NASA/CP-1999-209112

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Synthetic Vision Workshop 2

Compiled by
Lynda J. Kramer
Langley Research Center, Hampton, Virginia

March 1999

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Proceedings of a workshop sponsored by the
National Aeronautics and Space Administration,
Washington, D.C., and held at
Langley Research Center,
Hampton, Virginia
January 27-29, 1998

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23681-2199

March 1999

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FOREWORD

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The second NASA sponsored Workshop on Synthetic/Enhanced Vision (S/EV) Display Systems was conducted January 27-29, 1998 at the NASA Langley Research Center. The purpose of this workshop was to provide a forum for interested parties to discuss topics in the Synthetic Vision (SV) element of the NASA Aviation Safety Program and to encourage those interested parties to participate in the development, prototyping, and implementation of S/EV systems that enhance aviation safety. The SV element addresses the potential safety benefits of synthetic/enhanced vision display systems for low-end general aviation aircraft, high-end general aviation aircraft (business jets), and commercial transports. Attendance at this workshop consisted of about 112 persons including representatives from industry, the FAA, and other government organizations (NOAA, NIMA, etc.).

The workshop provided opportunities for interested individuals to give presentations on the state of the art in potentially applicable systems, as well as to discuss areas of research that might be considered for inclusion within the Synthetic Vision Element program to contribute to the reduction of the fatal aircraft accident rate. Panel discussions on topical areas such as databases, displays, certification issues, and sensors were conducted, with time allowed for audience participation. Most of the presentations focused on using SV to reduce Controlled Flight Into Terrain (CFIT) type accidents. It was also emphasized by several representatives that the airlines will need to see a cost benefit before installing new SV systems. It is believed the SV systems could provide expanded operations at airports during low visibility conditions, which in turn would provide an economic plus safety incentive to the airlines for SV systems.

This workshop emphasized the cost-effective use of synthetic/enhanced vision displays, worldwide terrain data bases, and GPS navigation to eliminate visibility-induced errors for all aircraft. At the time of the second workshop, a sensors development thrust was not envisioned to be a part of the SV element. The low-end thrust portion of the SV program will attempt to provide an affordable synthetic vision display system for the low-end general aviation aircraft operating in Visual Meteorological Conditions (VMC) to enable safe transit back to VMC in the event of the unplanned, inadvertent encounter of Instrument Meteorological Conditions, including low ceiling and low visibility weather conditions. It may also address loss of situation awareness and unusual attitude issues. The high-end thrust portion of the program will attempt to realize/demonstrate the potential safety benefits of synthetic / enhanced vision display systems for both high-end general aviation aircraft (business jet) and commercial transports to enhance situational awareness and tactical flight path management in low visibility weather conditions.

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Synthetic Vision Workshop 2
January 27 - 29, 1998

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8:30 - 8:35	Welcome	Carrie Walker, LaRC
8:35 - 8:50	Aviation Safety Program Office - Overview	Mike Lewis, LaRC
8:50 - 9:00	Current SV Program Definition	Lynda Foernsler, LaRC
9:00 - 9:15	Business Vehicles - NASA Research Announcement	Mike Durham, LaRC
9:15 - 10:15	**Panel One: Presentation Methods for 3-D Perspective Displays**	Chair: Tony Lambregts, FAA NRS Members: Baker, Beins, Foyle, Howells, Zuschlag
10:15 - 10:25	Break	
10:25 - 10:50	Example of DOD's Synthetic Vision	Al Brown, Boeing
10:55 - 11:20	URANIUM - United Research into Advanced Navigation InstrUMents	Erik Theusissen, Delft University
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1:20 - 1:55	4-D Flight Guidance Displays	Harro v. Viebahn, VDO Luftfahrtgeraete Werk
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1:10 - 1:25	DGPS Approach System	Pat Reines, Honeywell
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3:00 - 3:10	**Panel Four: Databases**	Chair: Ron Bolton, NOAA

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		Members: Bateman, Bolton, Burne, Burgess, Frank, Kerr, Leckman, Neilson, Norman, Norris, Ortiz, Shoucri, Symosek, Zeylmaker
Adjourn for the day		

Note: The following notes were taken in real-time at the workshop. Video tapes of the panel discussions were viewed after the workshop to verify and augment the notes which were done in real-time. Some portions of the panel discussions were not recorded due to technical difficulties. Hence, some of the entries in this Notes section may not be in complete sentences.

Synthetic Vision Workshop 2
January 27, 1998

<u>**WELCOME (Carrie Walker)**</u>
Good morning and welcome to LaRC. This is a very important event in the life of the Safety Program. This is the second workshop. Number one was a get acquainted. Objectives of first workshop were to: introduce Synthetic Vision Element (SVE), receive feedback, encourage involvement, discuss procurement process and establish panel sessions for workshop number two.

Panel topics for this second workshop are: Presentation Methods for 3-D Perspective Displays; What's Next After Predictive CFIT 2-D Displays; Just Do It--Can We or Can't We; Databases; and Advanced Vision and Sensor Technology Role.

The overall objective of the workshop is to further define the SVE. The format of the workshop is a combination of presentations and panel discussions. Some aspects of the workshop will precede to give background for problems. A product from this workshop will be the framework of a NASA Research Announcement (NRA) wherein we hope to gather information to put together the NRA. We see multi-organizational teams responding to the NRA.

Before Mike Lewis speaks, I would like to introduce:

Susan Conry, Secretary, CVIB, FDCD
Mike Lewis, Program Manager; AvSPO
Carrie Walker, Program Manager, ASPO
Lynda Foernsler, CVIB, FDCD
Russ Parrish, CVIB, FDCD
Mike Durham, AvSPO

<u>**AVIATION SAFETY PROGRAM OFFICE OVERVIEW (Mike Lewis)**</u>
Thanks Carrie. Good morning. I am going to give a quick introduction. Similar to last time. We have here a large international participation. I will give you my perspective as Director of the NASA Aviation Safety Program. Here is a quick background: The AvSPO sees safety as a global activity. If aviation is going to continue to grow at its current rate, we need to do something about the accident rate. Increasing traffic equals increasing accidents. Strong proposal coming from the Gore Commission was to set a target of 80 percent reduction in fatal aircraft accident rate over the next decade. NASA has signed up to develop a focused research program to make that happen. NASA has a Three Pillar goal, and goal number one is for safety. This Synthetic Vision Technology is an important part. NASA is only one part of what is needed to make it happen. Cannot

just do research. This program will be FAA, industry, and NASA--a partnership. Not just R&D. All pieces of the puzzle are needed to make this program work.

The philosophy of the program is we don't want (NASA) to pay for all of anything. We are not trying to buy from NASA a reduction in accident rate. Do not see trying to increase NASA budget. We have a set budget and will do what we can with it. NASA will be the potential catalyst (among industry, FAA and NASA) for R&T side- given appropriate ideas. We want an NRA to come out which will allow appropriate teaming which will make it all happen.

CFIT talks about aviation safety. Use wheel icon to talk about Aviation safety. An accident occurs when light shines through these rotating disks where holes (indicative of crew error, weather, aircraft faults, etc.) line up. Philosophy of this whole synthetic vision type of approach is that CFIT and loss of control accidents is a number one issue to attack. 30-40-50 percent of the aviation accidents are of this type. This is the problem we want to attack. The approach when I look at CFIT is pretty common to nearly 90 percent plus—is that the initiating event in CFIT and loss of control accidents is you cannot see well out the window. A potentially powerful way to attack CFIT and loss of control accidents is to think about the visibility part of the equation and attack that. Re-create daytime VMC (with Synthetic Vision Display system) to attack the whole problem. Visibility-induced crew errors is the problem. If you could see out the window, you could catch the mistake and the accident wouldn't happen.

Intriguing news is that GPS is more available. As is, data storage, digital processors (doubling every couple years), and glass displays. These technologies are the building blocks to the synthetic vision approach. No new inventions required. It is technology that's already available. Elements need to be systematized with a human factors approach. Lots of stuff needs to happen, but no new technology development. In order to make system effective, we need to rally around a particular approach. I see 3 goals: (1) eliminate CFIT by solving visibility problem, (2) provide affordable CFIT and loss of control avoidance for GA, and (3) use SV/perspective displays to provide stepping stone for future--all visibility/all runway manual operation. Lastly, the purpose of workshop is to identify key technical issues/hurdles, provide government/industry and industry/industry interchange. For our part we want to make sure NASA/government is doing the right kinds of things. Allow NASA to intelligently structure NRA (the solicitation) by making the statement of work to allow right teaming, to determine NASA's role, and right response from industry. Big deal for goal and for aviation world--we want to do it right. Little bit of separation in my mind. Money is not a concern with me right now. Funding will follow aggressiveness, attention, and interest of groups in this whole arena. NASA budget will not pay for everything. A part of making this work is that there is a powerful commercial opportunity in place. Wanting to do it right is the key.

CURRENT SYNTHETIC VISION PROGRAM DEFINITION (Lynda Foernsler)

Current program definition: Had a national goal to decrease fatal aircraft accident rate by 80 percent in 10 years and 90 percent in 20 years.

Type of accidents are loss of control of flight and CFIT which are major contributors to the fatality rate. Fatality rate anywhere from 30 to 40 percent in transport world is attributed to CFIT accidents. A great percentage of total aircraft accident rate are attributed to CFIT or loss of control in GA world.

Background information

• A lot of work has done from Don Bateman of Allied Signal. He is considered the father of the Ground Proximity Warning System (GPWS).
• Since 1958 over 8000 people have died due to CFIT accidents. Introduction of GPWS in the 1970's significantly reduced this number, but more still needs to be done.
• In 1991-1995, there were over 3000 fatalities in 59 transport accidents. 29% of these accidents were attributed to CFIT.
• In business jet arena-- 2 to 3 times more CFIT accidents in the business jets as compared to airlines.
• Primary cause of fatal accidents in GA is attributed to weather. Weather-related accidents usually involved controlled flight into terrain or other objects or uncontrolled flight because of
spatial disorientation.

Current CFIT Preventive Methods

• In December, it came out in the press that airlines were going to voluntarily put Enhanced Ground Proximity Warning System (EGPWS) on their transport airplanes.
• In 1992, Flight Safety Foundation (FSF) established a national goal of reducing CFIT accidents by 50 percent in 5 years (by 1997). FSF improved training methods for pilots and controllers by providing them CFIT avoidance information. FSF developed a CFIT checklist for pilots to assess a flight situation for the risk of CFIT.

Why SVE?

The majority of **CFIT accidents** (transport aircraft) and **Loss Of Control accidents** (GA aircraft) can be considered to be visibility-induced crew error, where **terrain visibility** would have been a substantial mitigating factor.

Many accidents happen because of poor visibility or night conditions. SVE will give pilot better vertical and lateral situational awareness. 66% of CFIT accidents have been attributed to poor vertical situational awareness. SV display systems present a picture to the pilot. He is able to picture where his aircraft is with respect to the terrain and picture where his plane's flight path is with respect to the terrain.

The goal of SVE is to eliminate visibility-induced crew errors for all aircraft (low-end GA, business jet, transport) through the use of 3-d perspective displays, onboard world-wide terrain databases and GPS navigation. By using these 3 elements, we hope to eliminate CFIT accidents for all phases of flight. Also, since GPS will be available, we can use it and 3-d perspective displays to provide the pilot with precision approach and landing guidance. We can use SV displays as a stepping stone for all visibility/all runway manual operations.

Use 3D perspective displays, GPS navigation and onboard terrain database to do CFIT prevention. Synthetic Vision Display System (SVDS) gives pilot a picture of the world. Hopefully this mental picture increases pilot's situation awareness. Can put horizon, velocity vector, or whatever flight symbology information is needed on SVDS. CGI gives pictorial view of the world, can be augmented with necessary flight information.

Within this program we are looking to prevent CFIT accidents in low visibility/night time conditions. Low-end thrust will provide an affordable synthetic vision display system for the low-end general aviation aircraft operating in Visual Meteorological Conditions (VMC) to transit back to VMC in the event of the unplanned, inadvertent encounter of Instrument Meteorological Conditions, including low ceiling and low visibility weather conditions. This system will provided the low-end GA pilot with attitude and terrain awareness. High-end thrust will realize/demonstrate the potential safety benefits of synthetic/enhanced vision display systems for both high-end general aviation aircraft (business jet) and commercial transports to enhance situational awareness and tactical flight path management in low visibility weather conditions. The approach used in low and high-end thrusts is to do system studies, piloted simulations, systems technology assessments and flight tests on candidate SVDS. Our anticipated partnership is to go to the user community— pilots, aircraft avionics/manufacturers, FAA, other government organizations, universities. Everyone working together to develop SVDS to eliminate CFIT and loss of control accidents. Starting in FY98 with 500K. NRA will be issued in January 1999.

BUSINESS VEHICLES - NASA RESEARCH ANNOUNCEMENT (Mike Durham)

Will talk some in regards to what Mike spoke of about partnering philosophy and hit lightly on business mechanisms that are available in the NRA. I will have a quick definition of NRA and why we are taking this approach. I will conclude with the desired partnership philosophy. We will look at what teams will provide back to NRA. At the end, we will touch on update access to an AWIN amendment on the webpage and on an asynchronic NRA and when and how it will be developed.

First area is the partnering philosophy. Philosophy for this program is to provide a funding catalyst and not pay all of anything approach. We will not take the redirected budget and buy a reduction in the aircraft accident rate . We do want to take funding and by working with you find the place we can attack and make a difference--that is what we want to invest. We intend to stretch industry timescales for investments and reduce NASA timelines. Encourage industry to invest in products a little further out (3-5 years)....be honest you (industry) are here to make a buck. Your challenge is pay for salaries and facilities next year not 5 years from now. By teaming with operators, subcontractors, and government we are able to look further out. Have time to recoup that amount of money. Will look for more effective research development. We want to cure the problem (accidents) instead of adding another band-aid to the cockpit. If look at the GA cockpit from 40, 50, 60 and 70's (none in 80's), we went from a nice simple flying machine to today's cockpit which is full of gadgets. We've added gadget after gadget to the cockpit. We need to clean up the collection of band-aids and make a system. Will take multiple teams of companies to do that. A new approach. Find a cure. Want to hear from you what is government's role and what industry can lift up and compete to make the aviation system better. What are right standards and procedures for this system? What is governmental role. In general, we want to increase risk tolerance through partnership and have system implementation provide more rapid ROI. As industry partners, you can lay down standards. Lower cost of the system and increase volume by developing system standards.

Moving on to business mechanisms. Look at how you do business with federal government. We want to do things differently. Need to use different tools. Aviation Safety Program does not have one answer. An array of tools will be used. Will use best tool for your team. In general there is a whole array from grants to classical fixed price contracts. Every box has an array of negotiating clauses and uses. What I am trying to show is that there is probably a best approach with the different business tools depending on technical research to be done. Want to choose the right tool in terms of technical research being done. Depends on what government is buying o determine what business mechanism should be used. If what we are paying for is an investment in industry standards, than industry needs to be co-funded. What I want to steer you to is the middle—Aviation Safety Program should focus on cooperative research agreements. They are cost-shared and co-managed. They are very powerful for developing teams. They can have multiple competing cooperative research agreements. Not as much government control, but influence and relevance for national effectiveness. Government is giving up control, but getting more influence. Alluding to NRA--NASA Research Announcement. A fairly open, flexible solicitation where government is saying we want to work in this area and we have some ideas, but we need industry to tell us what they think needs to be done and what type of business mechanism should be used. A request for research proposals conceived by offerors in broad technical areas. Used where impossible to address specifications in sufficient detail. An NRA approach can be used wherein there is a multiplicity of approaches. NRA cannot be used in place of a RFP. Multiple awards can result from single NRA. NASA determines appropriate business instrument to come back and negotiate the terms of. Contracts resulting from an NRA are subject to the Federal Acquisition Regulations.

Desired SV proposal attributes: teamed proposals with proper technical breadth/focus and direction to contribute to 10 times goal, partnership representing aviation community, consider complete path from technology development to test to certification of implementation, efficiently managed team through one prime (a business agreement with sole business partner.). Proposals which are data-driven, metrics-monitored. Proposals need to specify transition path, including issues like interoperability and upgradeability.

QUESTIONS AND COMMENTS for Mike Durham

Question: Does this alliance have to have joint venture...can have single contract.
Answer: Yes. Not much of an entity to do that. Front end of business office (legal agreement)...

Question: In regard to emphasis on cooperative agreements, are you contemplating a fast track method to provide legal support?
Answer: We will not come in and help make individual agreements within your team, but this investment by the team will bring an overall savings in the long term. Far less red tape in dealing with government for life of contract. Not same reporting

requirements. A trade off. Government will provide generic cooperative agreement between us and the entity. A price up front but easier to deal with fed government through cooperative agreement--that part will pay for itself. Facilitators out in the business world that can help you. I do emphasize that you need to start teaming now. Don't wait for NRA to come out. Deadline for proposals has been extended for AWIN NRA.

Question: When is SV solicitation coming out?
Answer: Summer 98

PANEL ONE : Presentation Methods for 3-D Perspective Displays
Chair – Tony Lambregts
Members: Jorg Baker, Ross Beins, Dave Foyle, Pete Howells, Michael Zuschlag

Tony Lambregts, FAA (NRS for Flight Controls): From time to time we get drawn back to presentation methods of 3D perspective displays. Not entirely clear yet what the territory of operation is for this research. One of the first ideas I struggle with is there may be a clear aspect of increasing the use in GA aircraft and one impediment is weather. If there is weather and you have to fly in instrument conditions and don't have training you can't do it. If you get into instrument flight conditions inadvertently that is one of the bigger risk. First thought is are we going to putting on more sophisticated display /guidance systems for the less skilled pilots and draw these pilots into more dangerous situations and create more accidents. We set out to make things safer but inadvertently we make things unsafe--something to contemplate. Another aspect is if you draw on sophisticated technologies--there is a price tag--if too high going to have very limited chance in selling your product--need to keep this in mind. Have recently signed up w/FAA that means certification. If you come up w/good ideas before you can sell it and put on airplane going to have to certify it. Certification can be a very daunting task and the main problem with certification is not so much you don't have idea right but main problem is you have to look at angles of what can go wrong with product that you provide. It means you have to have systems engineering, integrity, the right safe guards in cases where it doesn't function. These aspects are much more difficult to bring to fruition than just the basic idea. These are the things I will throw out for comments.

Jim Daum, Boeing Helicopters: Want to comment about earlier statement of making IMC/VMC. Think what you bring up is if we just make a system for when pilot is getting in trouble and not using it all the time then they won't have the experience necessary when they go to use this product. I propose that we make the product. Another issue is why does a pilot want to have this device on when the weather is good. We need to make the product so it enhances his ability even during VMC flight. You give him increased enhancement for navigational cues, give him pathways to the sky, make him want to use even when it is VMC. So just by limiting to loss of control during inadvertent IMC --is limiting ourselves. We want to make IMC flight/VMC flight or even better make him use this as his primary instrument for navigation, flight control, etc. Must make him feel he'd rather use this then look outside.

Tony? No doubt that it has to be something that's used. Bigger problem is it must be implemented in a much the larger percentage of the population than currently exists.

Phil Brooks, Allied Pilots Association: Had a meeting w/technical pilots and the manager of Flight Operations Safety and they talked certification, certification, certification. I would submit that we have opportunities to innovate in certification front. Aware of work of a Mr. Burt Green in getting HUD displays on transport aircraft. Right now Aerospace Recommended Practice for HUDs, ARP5288, is currently under revision by the Society of Automotive Engineers to be submitted to the FAA as operating standard to certificate HUDs. Other airlines are now operating HUDs. Happened because Mr. Green wrote a document and through certification pushed it through under what is termed a special condition. Believe that synthetic product(s) that come forth out of this program will have to be certified by documenting what we are doing as we go along so by the time we have the product we will also have the manual that goes with it and they go to the FAA and say special conditions certification and then SAE afterwards and write up a formal standard. Convinced certification is the hinge upon which this whole thing hangs. Would appreciate any comments from the panel on any insights in how we can do this.

Tony Lambregts, FAA: If we make a product that a VFR pilot can use to get out of IMC conditions, the Feds will probably be understandable and certify it if it is that good.

Comment: Will comment on certification of HUDS. Very difficult. Lot of problems with presenting pilots w/ information because it has to be of high integrity. Takes a lot of time to certify those HUDS. Another comment is that of cost benefits, up to this year the only reason we got system on airplanes, is justifying by saying increase the number of landings; although when system on airplane HUD is seen as situation awareness enhancer--now airlines and users are starting to understand that and are coming through saying they are installing because of situation awareness instead of commercial benefits--think we are seeing a change. Big issue is to convince the customers the system is going to enhance situation awareness. I think this is one of the biggest challenges.

Comment: There is a distinct difference between making a display that is intended to get a pilot out of IMC conditions and making a display that is intended to work both VMC/IMC conditions. Two very serious problems with this is (1) it is very difficult to duplicate all of information that a pilot uses during VMC conditions on a display. Done a lot of research into this and I don't think you are going to do it. (2) Comment made about making system so good that you don't have to look out the window. This is just what I am afraid of. If you make it (the system) more compelling than reality, we have seen where pilots are drawn to displays even in the presence of information contrary to what's on the display and they will inadvertently go to the display because it looks so good not because of the integrity of the information that's contained there. So I'm concerned if you make a display intended for emergency operations only and the pilot uses it all the time--maybe there is an inferred reliability/trust that is not there. Must make sure we don't build something that is misleading.

Tom Leard, Honeywell:. In regards to making your way out of IMC versus having a display you use all the time. I would submit that in our training process for initial private pilot we talk about integrated training approach where altitude and instrument flying is integrated in as part of the learning/flying process. I would submit that even today's air driven, unsophisticated but effective attitude indicator or air speed indicator or altimeter are used time and time again from earliest time frame and they present a good model for how we would want to develop this CFIT preventing system in how we want to train and use. The question is where should we draw the line relative to where a 3D perspective display would best be presented. Is it best presented given all the issues in the primary flight display environment (or aviator display) or more appropriately displayed in what we call the navigation display which some would argue is a multi-function navigation display environment?

Comment: I think there is a pretty straight forward answer to this. Can you present both navigation and primary flight display information in one unit in one synthetic vision display. Another alternative is you can have switchable modules and if person flying and he wants a pitch ladder and a horizon line in his synthetic vision display he can select that. If he does want that and there is clear visibility outside of the wind he just looks out of window he does not need his pitch ladder. He has outside references--he can do fine and yet he would still have a synthetic vision display that might have a high way in the sky--it might mark the airports he's going to. He can look out the window to see 8 or 10 miles but he cannot make out airport on the terrain; but yet his synthetic vision display is marked and he can see where it is relative to the plane so he can see what way to go. Many times flown up to airports that are grass strips and been right over them and still had a hard time flying. If it had not been a couple of airplanes on the ground, I probably would not have found it. To have those marked in a synthetic vision display might be an assist in that kind of situation.

Comment: Perhaps the distinction is not so much between navigation and primary flight displays as between tactical information and strategic information. I think the synthetic vision displays provide more tactical information more or less short term information up to a few miles ahead; perhaps would augment with navigation displays, but it is not going to tell you what's behind you if you're making an approach with a large curve won't show you what is over on the other side of the curve of the earth so that might be more of a role for secondary displays such as the navigation display.

Comment: I think synthetic vision right now with the display we have the user can actually browse a terrain and as he is navigating we take the GPS input and show what things look like out in front of him, but if he's coming up on a hill he's got a certain range and if he does not know what is over that hill he can actually browse that 3D terrain and throw his altitude up and take a look at that hill in that synthetic vision display and see. He can take a look behind, forward, aft, left, and right and see what's around him. He can actually look ahead in lat and long and browse any point in the database and take a look around in that terrain and than after so many seconds the display will snap back to where he is and present his navigation display as he's navigating. So I think it can be a combination of both of those. Also were finding working with different DEM models, you have two things--the accuracy issue and resolution--the fewer data points you have on your DEM model no matter what CPU your using you can look further ahead and that is a pretty powerful tool also. But if your try to resolve things down to a very high resolution with DEM models you start chopping up the CPU power so much that you're not going to get a long range terrain display.

Comment: I think we should look at CFIT as more than just control flight into the terrain because it should be control flight into trouble and I don't think we should define too narrowly. A gentleman earlier commented about being scared the pilot would not look out the windshield if he had a SVDS. Reality states that we have to look at this towards the future anyway. I am not saying you should not have pilots looking out the windshield--that's not a good idea. What I am saying is whatever you do should not be predicated on having a windshield to look out of--it may not be there by the time we implement this kind of system. Just think we should open up our thoughts to all of the trouble we may fly into.

Sy Levine, SISTMS: I think control flight into trouble should be the definition. We are talking about database (DB) systems. DB systems were done in marine and they got into trouble unless you see the things in front of you that are not in the data base you got planes flying and all other sorts of targets. In addition these forward sensors allow you to validate the DB. If you look at the DTED data used for cruise missiles you get an idea of what the altitudes are and therefore you can put together with the ends. On the GA it is more difficult problem because of the dollar issues on the big planes on this whole idea of integrating what is CFIT. I notice all the ones previously had GPS, data storage, visualizing, glass display--where is the other data which is planes, air traffic, collisions, etc. That whole thing has to be put together as an integrated system.

Comment: I have been looking at that to and we want to present some of that information and basically it is a matter of obtaining the information. We can obtain it by sensors, by data link but it is really getting into the cockpit. Once you get a computer in the cockpit, you can do wonderful things with it as long as can crunch the right numbers and the right data through it. If we can get weather information up, we can lay weather over the chart or we can put a big red blob in the sky that shows severe turbulence. Or we could put some other thing between the runway and the pilot showing him there's a down draft and you are going to get a free ride into terrain with micro burst if you don't know about this and we could put that microburst right in front of him. Question is how do you get it into the cockpit and that gets into data link areas and FAA is working on that. Not difficult to do just requires a national implementation. We can show you in synthetic vision display the traffic, traffic vector, can delete out presentation of aircraft that is not relevant to flight but we need to get the data in and maybe that data is available to us on the TCAS system. That is something I need to find out.

Steve Young, LaRC: Been working on presenting synthetic vision to pilots on the airport surface along with Dr. Foyle. What I want to ask the human factors people is there a compelling argument when you compare enhanced ground prox auditory alerts vs. visual reproduction of a visual scene. Is there argument for or against either of these approaches.

Comment: There are several things you can provide. First not either/or. You can combine them. In fact the Honeywell system does combine them with a plan view of the terrain in addition to auditory alerts. Lot of things you can show with visual representation that you cannot show with auditory which is why they can augment each other. By showing terrain visually especially in perspective display has potential of showing escape routes so don't just have to go auditory command if you find turning away from terrain might be better for a particular terrain. Also can give you a preview of terrain before you get so close it is going to trigger an auditory alarm. You can tell if it's rising or falling terrain. Use this to plan your path before you get into an auditory alert.

Comment: The organizers of the panels wanted to stick to the question of what about presentation methods on 3D type perspective display. So would like to draw audience back to this which is totally new wherein most of data dealt with has been 1D single instrument providing a bit of information either in an analog way or numerical way. All of sudden we have possibility with new display technologies to go to 2D (planform) or we have a 3D capability. Think this is what this panel is to address and what about these new dimensions we can use in displays--is that important to safety.

George Kaseote, FAA: In response to the United Airline gentleman on the GPWS. During the ??? accident GPWS was screaming. In the human factors area we need to look at more alerting situation the further down the line you go. In Guam accident there were all sorts of audio cues. The crew got calls at 500, 100, 50, 40, 30,20, 10 into the ground. We need work in the human factors area.

Comment: This is a really good point and this becomes a point of information overload. You have instruments you are reading instruments and they are 1D and they require interpretation and you have to go through interpretation process to figure out what your situation is and then when you get into navigating its even more abstract process to figure out your location and then when you go into navigating in 3D in relation to terrain it is almost virtually impossible with current instrumentation in aircraft to really know what the terrain is below you if you can't see it. 3D navigation gets very difficult. If somebody's making an approach with alarms going off, they become disoriented and in a state of confusion. Need to keep pilot oriented so he can see where he is. If he does become disoriented just look at display. This goes way back as information overload— Goes back to Vietnam pilots with people talking to them, alarms going off this makes the pilot turn switch off and look out the window for SAMS because he does not want to hear it all. Have to be very careful as to what we want to present the pilot with. Don't want to load up synthetic display so that it's cloogy. The approach of display is something we have to have great caution with.

Comment: Along these same lines have a concern that this area (over the years) has been very hardware driven in terms of specific capabilities. I think that it is important to step back from that and design whatever system is proposed or sets of systems that is human centered. Important to have a process to have to go through formal testing and formal evaluation. But before that, you have to see what is the problem--what are the information requirements that you are designing for. Need to understand from an informational point of view what the pilot needs.

Doug Trumbull, Entertainment Design Workshop: In the entertainment business we often photograph information 180 degrees wide so we can fill the entire human field of view and present in hemispheric display system. We also can superimpose natural human field of view reality with graphic computer images and layer with perfect registration. So it is possible to take graphical display of terrain or air corridors or flight path and superimpose it over reality. I think the technical challenges of getting that synthetic reality superimpose over reality out the window of aircraft is a minor task. Don't think you want to look down at anything. You want to look out the window. My philosophy is to take some of the best knowledge of the flight simulation industry and get yourself a new superior image out the window. Superimpose over natural reality--like a HUD a that's 180 degrees wide.

Comment: Sounds very impressive to me but are we still in financial reality.

Doug Trumbull: Cost of graphic accelerator cards for PCs or laptops are extremely low and extremely powerful. In addition in talking 3D displays which I think what is meant is XYZ-coordinate geometry of some kind of display 2D on a flat screen. I think stereoscopic vision is extremely important human perceptive quality that is very profound and powerful and think stereopsis ought to be included in factor of display to pilots.

Kim Kaiser, Alaska Airlines: Want to give operator perspective to guidance vs. a display. Been run Enhanced Ground Prox on our airplane for a year and find a significant change in the crew operation on not even getting into an alert situation. Particularly in a simulation when we try to set up to get them into a ground prox event and it is very difficult if not impossible to get them there if they have the terrain map up in front of them--have to end up taking the map away to get into actual alert. Also to support idea raised about certification. If it had not been for intervention of higher level certification pilot over the one responsible for our EGPWS effort, we might not have it yet.

Comment: Intuitive situational awareness is the key. Can't train people to recognize the information you are giving them--it has to be there intuitively. Key is to present information in an intuitively way.

Comment: Important to realize whatever is built and put into the cockpit has to be integrated into the air space. There have been concerns when TCAS came out that maybe integration into the air space w/controller could have been better. Still reports about confusion of pilot going off and doing something and questioning what the pilot is doing. Realize there are integration issues as well as display issues.

Comment: Pilots want intuitive information that doesn't have to be mentally integrated. We want the terrain displayed but also want the guidance there--then want intuitive guidance because relationship between guidance and terrain is fundamental to pilots in terms of spatial awareness. Need to know where we are going and where we don't want to go.

PANEL TWO: What's Next After Predictive CFIT 2-D Displays?

Chair – Mike Norman
Members – Don Bateman, Bill Langdon, Paul Leckman, Charlie Wood

Mike Norman, Boeing Co.: Pilots are often workload and information saturated in the current cockpit environment. More information doesn't necessarily mean more safety. Should provide tactical (what to do) and strategic (why to do it) information in balanced amounts. Shouldn't apply technology just because we can. We should take a requirements-driven approach to achieve the best pilot and organizational buy-in. Just to put into perspective what we're doing - Think of the last 10 aviation accidents particularly the commercial aviation accidents. Some of the amazing chain of events that caused these accidents and now of some of what it would take to prevent 9 out 10 of those accidents--institutionally that is not putting yourself in the cockpit and stopping it from happening--but stopping it from happening beforehand. I think you will see we are getting more into just first order things but second order things--that's the challenge ahead.

Paul Leckman, Boeing Co.: I am a research pilot from the Boeing Co. I spent last 2 years trying to pave the way for installation of enhanced ground prox on our Boeing airplanes with Don Bateman. Don Bateman deserves every award he's received. He's done the risky things such as trying to get a terrain database on a transport airplane. He's got a terrain database of the world and got it certified w/the FAA. That is the kind of effort that is going to be required for a perspective display. Want to direct an answer to Mike Frank's question. If you have enhanced ground prox now, why would you need a perspective display? In my mind, the error avoidance is what's in front of you--is it the runway or hill. The difference if you look at enhanced ground prox, it really does a really good job of telling where you should not have gone after you have gone there. With a map there is really no reason to get a caution/warning with an enhanced ground prox system if you are watching the map. There are certain cases where you can make large errors and it goes for quite some time before you get a warning. You are basically warning someone after you have deviated substantially. A quick picture can prevent that deviation in the first place. You're improving recognition time; for example if you roll out on final and you are so low that there is a hill between you and the runway that might be visible. And earlier and inappropriate descent if you have a runway on your perspective display and your are at 1 degree off that runway, a descent at that point is probably not appropriate. Usually try to stabilize approach at 3 degrees and that information always available on the final. In some cases, for example the ??? accident where the crew is trying to comply with an ATC request that was inappropriate and may have been determined that way through the enhanced ground prox system but a forward picture also adds to that. In addition, the display ahead of you shows the azimuth vs. a climb angle requirement. The amount of height above the airplane is not as important as the climb angle required to clear it. Improved approach stability with perspective display will give you similar information as to HUD angle to the runway and the ability to stabilize an approach. There have been perhaps not CFIT/classified as CFIT accidents cases where you're under shoot the runway because you let the speed get low or you're trying to descend rapidly as you weren't aware you were too high until the last minute so you ride low close into the runway w/a speed and configuration that was inappropriate. It might even help w/over shooting a runway and economically perhaps there is a benefit for consistent configurations changes when they are appropriate to get down. Low visibility taxi operations - this may or may not turn out to be useful. Being studied by SAE right now. Cockpit display of traffic information - may or may not be useful to have forward look at traffic as well as the map display. Where companies install HUDs - there is a potential of the perspective display to have similar type of display for co-pilot who does not have a HUD.

Charlie Wood, Douglas Product Division: Have lost 4 friends due to CFIT accidents. Ask myself how can a state of the art airplane run into the mountains? I wrote a paper and put down thoughts as to why this happens and a What Do We Do Next chapter turned into what I call the "Standalone Terrain Conflict Detector." This is an idea I came up with and it turned into a disclosure I made to McDonnell Douglas who in turned filed a patent application for it. Basically a device about the size of a lap top computer that you can put on any airplane, self contained, with a terrain database. Basically stand-alone--one pilot's idea on how to prevent CFIT accidents. The only reason airplanes run into mountains is simply because the pilots did not know where they were--all the rest of the reasons are contributory. Why didn't they know where they were? Before FMS, it was very difficult for pilot to determine where they were. FMS was a quantum leap in situation awareness because the map display really tells you where you are relative to your flight plan. There are some problems with these if you fly a long over water leg for your IRS navigation only for quite some time and then you go into country that doesn't have a lot of DME's you map could shift. I'm talking as much as 8 miles from where you really are--don't think this is acceptable. Already talked about deficiencies in the standard. GPWS which again was a quantum leap when it was implemented but it only has the capability to look straight down. The EGPWS is also a quantum leap because it does give you a look ahead capability and give you its warning of approaching terrain. My device, the Standalone Terrain Conflict Detector, relies on GPS for signal. Military degrading systems GPS is still accurate within a 100 meters--normal accuracy is around 10 meters. My device requires accurate terrain and man-made obstacles information to be put into database. It requires predictive flight path vector display to show you where you are going to be. I feel we need even more warning than the advanced GPWS so that pilots can make normal maneuvers and avoid obstacles. First it has to be affordable for every airplane owner in the world--that is what is being ask for. First have GPS signal giving you an accurate map and I had a flight plan capability to put into this also. Next we have a terrain obstacle database which shows you terrain or obstacles that are above your predictive flight path vector. In other words, I put the red for anything that is above your predictive flight path vector. I put a little 100 meter pad in to show possible error in the GPS. It is easy to see in bird's eye view throughout your flight where any terrain above your flight path vector is. If you get off course (I say at least 4 1/2 minutes from running into obstacle) you get a wake up call. Normally this map display is passive--you don't have to look at it at any time during the flight--it is not a primary flight instrument. However, if you approach an obstacle and get a wake up call, then you can look at the screen--terrain ahead. You get this warning in time that you can actually determine an escape route before the terrain became a real serious threat. If you continue to ignore this, then you would get a pop up display that would give you a look ahead view of the terrain or obstacles. Again, red depicts anything above the flight path vector. Training is a big issue w/airlines--it cost a lot. My idea of training with this device is don't fly into the red or your dead. Simple as that. In the device there are indicators in the middle, the first little airplane is you. I find I can fly better if I mentally sit behind myself and watch myself fly. Second one is one minute, the third is two minutes away--a function of time. As they go faster they move further apart. To do a maneuver you can pull up to fly over the obstacles or you can bend your predictive flight path around the obstacles. As soon as the indicator turns green, it means your predictive flight path is clear of the obstacles. The 3D color graphics really enhances situational awareness. It lets the pilot see where they are, see where the obstacles are, and see where the airplanes are going. It is easy to see the best escape route. (At this point a demonstration was shown on video).

Bill Langdon, United Airlines: Let me give you a scenario first. A young lieutenant in a F-16 flying off runway - bad weather, low visibility, low ceilings. Take off is a simple task of instrument departure following his lead in radar trail. Takes off and about 1 minute after takeoff something doesn't sound right. He in a high tech aircraft with displays everywhere--he's got HUD w/instrument capability, radar w/ground map capability, regular flight instruments and backup instruments but something just doesn't sound right. He looks up and his primary instrument tells him he's in 135 degrees of bank, 60 degrees nose low and going 450 knots and where did he get the indication--it wasn't from any of these instruments--it was from his ears saying the wind rush--something is wrong because I am going fast and shouldn't be on the departure. So what does he do? He rolls wings level through the horizon, puts the nose up 45 degrees, turns afterburners on and climbs 35000 ft immediately. What gave him the cue on this is the wind rush in the ears. He had all this information presented to him but he got focussed on one thing and that's the radar to follow his lead. What happened to this pilot is that he got task saturated. He got in a position where he was not concentrating on what he should have been concentrating which was flying a departure--instead of finding his lead out there on the radar. How do I know? Because I was that pilot. I was two seconds away from impact. Only way I got out was pulling 7G's. What's happening is a lot information going in but the right information has to be processed. For many years the HUD in F-16's was not allowed to be used as a primary flight reference. It was written in our regulations. Why was that? Because human factors are not involved in design of in the instrument capability of that HUD. That HUD was put in that airplane to deliver weapons. It wasn't meant for instrument referencing. What I did is some research into HUD displays to see what was causing some of this. With Calspan's help, we designed a HUD that was more instrument oriented so that pilots could recover--they had pointers to the horizon to get them there--human factors were built in. My first point here is human factors is number 1. Got to put human factors in the beginning and other things can follow; otherwise, run into a bad situation. Now will talk about needs. Is control flight into terrain a problem in the airline industry? My point of view and United's is that it is not a factor right now. United implemented procedures way back to prevent some of these things and American did not have the procedures. Problem in airline industry is that we don't talk to each other. We don't visit each other's training facilities and see what procedures have been implemented and make sure those safety related procedures are then brought out throughout the industry. So that's our fault. CFIT in up and away, cruise flight is definitely no problem because mostly fly at night anyway. We are going to install EGPWS in our airplanes and all will be retrofitting by the year 2000. I think this is a step in the right direction. Would like to see what is becoming terrain out there. Would like to talk TCAS. I was flying to South America in Brazilian airspace and I got "traffic traffic" following immediately by "descend now." On my display it comes up where to put the airplane to descend now to get away from that person. No radar control where I was at. While I am looking at on EGPWS and other new systems for terrain avoidance why not have something in there that tells me where to go. I don't need to see the ground. I need to be told where to go to get away from that mountain. Need for it to give me a path. Instead of showing me all these ground pictures which starts a saturation of information--got too much information coming in looking at all these displays. United is not against developing synthetic displays at all. Think they would like to see development go on. Are we going to spend our money to do this? I don't think so. Reason being is that they are looking more for something that's going to pay off big in safety. The reason we are putting EGPWS in our airplanes is because of safety and that's going to pay off good in situational awareness and safety. But are we going to pay multitudes of dollars to be able to see the ground? I don't think so. Unless it pays off in safety or cost savings for the airline, then I think that is the only thing United is going to look at or any airline industry for that matter. Some safety issues we are looking at are clear air turbulence, but CFIT is not one of those areas we are really too concerned about. CFIT numbers are really down in the U.S. Where is the concern with CFIT? Concern I believe is in the approach landing phase. How can we tie that into a cost reduction revenue producer to get them interested in helping CFIT problem. One way is to develop systems that can get you into any airport that does not have a CAT 2, CAT 3 capability and get you in safely and not have a divert, not have extra fuel. What are pilots going to fly? First if you put a virtual display in and you ask captains at United airlines would they fly w/the virtual display being your sole source. They would say no way I will not fly a virtual display down to a runway and land off it. They want real time data out there. Now if you put sensors on and you put sensors showing HUD display would they land off that. I would say no again. They want real time information coming into the cockpit. Where we get real time information is from procedures. We want this backed up with information but not cluttered so much that it takes away that information. This is what you find pilots want today. Going to find you have a hard sell with the new stuff. Not so much age in reference to computers but age in reference to experience--experience tells them that I need to see some real pictures. Believe sensors and virtual technology display have to be integrated together. NASA has to be the coordinating body behind this whole thing. Have to determine the needs first and make sure we go towards those needs and may be put it in to a revenue type approach for the industry to make it appealing to them. Hate to see people going along in parallel tracks. Need to find out what technologies are out there and see who needs to be contacted to do this so there's no parallel tracking research. Again would like to say (1) human factors is number 1, (2) lots of new technology, but need to first find out what the needs are, and (3) how can we make new technologies cost driven to produce income for airlines as well as creating safety for air carriers of the future.

__George Kaseote, FAA__: Going back to Don Bateman--on your gear that flaps down problem, can that not be mechanized something like the two low flap switch or the glide slop switch such that it will still operate until you get within a mile of the runway? Can it not be mechanized off of DME or some other thing?

__Don Bateman, Allied Signal__: If we had a glide slope on every approach it would be a pilot's dream. With DME it may be different places other than the runway. Old problem. If you take any alert system and you try to make it work going to have to shut it off eventually when you try to land--automatically w/o the pilot having unwanted warnings and so on. Wished we could do something. The terrain clearance floor in the enhanced view is an attempt using runway position, runway ends, knowing where airplane is and doing it automatically w/o the geared flap.

Comment: In regards to Cali accident - I say yes it would have been prevented. I am one of Don's pilots who flew his system. My profound statement on the EGPWS is (and I've been flying for 43 years) if you want to fly to the ground in that system you are going to have to want to fly in to the ground.

Don Bateman: You don't have to wait for an alert or warning.

Jim Daum, Boeing: Have to reiterate what Bill Hines says. There is another community out there who would use this at lower altitudes. With tilt-rotor abilities to come in and provide commuter service. It will now open up with the runway for more departures and arrivals for the big guys. Because the tilt-rotors operate in that lower altitude community and need the greater performance and resolution at lower altitudes I don't think you should push off to the side and really take heart that community will help you out.

Comment: I think on the contrary we are looking for overlapping needs and requirements.

Comment: Given Alaska's experience with HUD, one pilot said he wouldn't fly HUDs and learned to love it. Given our experience so far EGPWS, the massive situational awareness increase all the pilots swear by, and given the fact we are flying essentially virtual reality R&P approaches where there is absolutely no conventional navaid backup and download and terrain on both sides of the aircraft, Alaska will be very eager to partnership with anybody who wants to develop this kind of system and look to get it on our airplanes as soon as it is available.

???, Germany: As vice chairman of ADO committee I presented a video 3D at the last committee meeting and it resulted in ARPA strongly supporting the development of a terrain and position awareness system. For example, projects such as the 3D flight guidance display system research and ARPA ultimately believes the requirements and installation of EGPWS would not be required if such a system were to certified and fitted. As a pilot who has flown the system, it is not supposed to be a 0/0 system. The possibilities of a whole system having to implement fans, ADSB, TCAS, or just having a hazard warning and escape possibility within the system. Also with the TCAS possibility has a chance for the airlines to make real big money if installed this on the economic side as well as the safety side.

Tom Leard, Honeywell: If 3D displays provide the opportunity or terrain displays provide the opportunity for a line pilot to have category 2 capability without re-certification every x number of months, without calibration of equipment every x number months, that is a tremendous ability and mission completion capability. I think if those things came to pass because of technology integration in the cockpit, the economics would be immediately obvious to every operator. Seems like a tremendous economic incentive to make this work. Whatever the right mix of data is to making the cockpit. Ala - what are the right requirements.

Comment: I agree with you 100 percent. What stands in the way of some of this stuff is how far is the pilot going to go with virtual displays and that kind of thing . Because it's nice to tell the airlines, yes, we have this virtual display that will get you in anywhere. You don't have to have a category 3. You can fly a flight path through the sky. But you're going to have a lot of resistance from the pilot force and it's going to be hard to overcome that. I am not saying that it's not do-able, but if you can make it cost effective to the airlines to do that than ALPA has to help sell it to the pilots also.

January 28, 1998

PANEL THREE : Just Do It - Can We or Can't We?

Chair: Tom Leard
Members: George Boucek, Phil Brooks, Bill Corwin, Doug Trumbull

Tom Leard, Honeywell: I put together a talk about issues that have surfaced at this workshop thus far. Areas of certification...The panel will give us their perspective as to what is ready now, what isn't, retrospect issues, and certification obstacles.

I am a Human Center Design Specialist. The primary focus is on business of human design...Really fits into area that I have been working on. In that background, reflecting what we are involved in. I worked as a test pilot at DER, Long Beach, California. If I go further back I can include time spent in a variety of...somewhere back there is working in the training business. Training is one of the key pieces of a human design process. Variety of typewriting. I also spent time in the U.S. Air Force.

George Boucek, Boeing: I have been with Boeing 30 years. Set up human factors plan for...777 program. I am a Program manager for the FAA sponsored work on crew alerting which resulted in ICA system and synopsis and checklist programs. I want to expand on what Dave Foyle said and in the context of this panel. The answer I would give is yes because technology is there. The real question is should we? What are the requirements to find out what is? Look at integrated technology of the flight deck...retrofit, employ across customers...whatever the marketplace will define. What should we be doing still remains unknown. What Russ has asked is the requirements given vs. solution given approach. What I mean is the actual or more closely system specifications requirements. I would define autoland system. To land +/- 27 feet of runway centerline. To reduce aviation safety is not a requirement--it is a goal. We need to make goals and requirements separate terms. It is a goal to increase safety and reduce by 80-90% depending on timeframe, but if we do that in a system different than this it is a system where the pilot is the critical component , which we then work what Tom alluded to--a crew system concept. Initial building blocks are to determine what we have to do with the crew to achieve the goal we are looking for. Like Foyle said...decide what technology to use to implement changes/functions that the crew needs to work or be critical component. Defining those requirements/functions have to be our upfront effort. We can talk a lot about technology and what exists, but until we determine the function we want to perform, the technology...we can't do a good job in talking about technology. Until we determine the functions that we want to perform with technology the functionality or better yet the marketplace can determine what technology is applied. Can do same functions in GA, rotorcraft, military and commercial by vastly different technology. First I have to determine what it is you want to do. [Showed cartoon]. I leave you with the words: we have to determine the requirements, but they are not really the goals.

Bill Corwin, Honeywell: This should be a requirements-driven program. On my flight out here, I looked at a report from the ASRS program at NASA about controlled flights toward terrain. What is new and different about control flight toward terrain? With regard to what Don Bateman said about lack of MSAW warnings in ATC software around the world. Looking at descents. Where you descend from altitude -between 10K and the runway – and you haven't rolled out onto the runway heading. There are a few airports where this is a problematic (Las Vegas, Tennessee, and Portland). It is interesting to note that we ought to be thinking about installing the same software into the controller's workstation that goes into an airplane. Speech recognition technology is not far away and should be installed on EGPWS. The controller should be aware as well.

What is the motivation for reducing CFIT? First and foremost, the tragic loss of life associated with it. CFIT is bad for air carrier business. Litigation settlements are very costly. Yesterday, the fellow from United said they were not interested (as a principal thrust) in CFIT avoidance right now. My reaction is - Until you have one (CFIT accident) in the near future. Russell Chew of American Airlines has written an argument about the business cases of why airlines do things--revenue enhancement, cost avoidance, competitive position. Revenue enhancement: Will equipping the aircraft with PFD provide the carrier a new capability? No. Cost Avoidance? Yes. Settlement associated with litigation is prohibitively large. Is it a competitive position? Yes. AAL is equipping it's fleet with EGPWS. The paying passenger public is getting smarter.

My homework assignment from Lynda was to answer five questions. Integration of synthetic vision display with existing displays. I am taking a technology perspective on this. Can it be done? Yes. Why not ground portion of the ADI as we've seen in the demonstrations so far. Can it be done in existing CRTs/AMLCDs? Probably not, likely it's cheaper to replace display unit and symbol generator. What is ready now? The terrain database. I stand corrected per what Don Bateman says that is not ready. What isn't ready besides terrain database? Perspective scene rendering on avionics grade displays (not what we've seen today). Retrofit of Synthetic vision display into existing aircraft requirements. The FARS are not mystical, not hard to interpret. The scene must be accurate and correctly registered on the actual world view. Certification obstacles. The process itself can be an obstacle. Clear criteria must be identified. The dialog (applicant/FAA) must be candid and timely. May be great that FAA is re-addressing themselves to process of certification. Have to have candid dialog. Can we do it? Yes. Should we do it? Yes. Technology will save lives. Technology will be cost effective for the airlines in the long run. We should do it with all possible haste. I am an avionics guy and Don Bateman is my hero. He has saved so many lives.

Phil Brooks, Allied Pilots Association: I am representing the Allied Pilots Association. Ladies and Gentleman, American Airlines through which I am a pilot for feels like this is very important moment (as was mentioned on December 11) in history. We also think it will happen soon. I ran across a quote from Gerta, "Whatever you can do or dream you can, begin it. Boldness has genius power and magic in it." The phrase just do it--I would say must do it. When talking about pilot requirements this is what we believe: A pilot's vision is a cornerstone upon which everything in aviation rests. So combining both an intuitive perspective view of terrain using real world visual cues with visual highway-type display of guidance is absolutely paramount because managing the relationship between terrain and flight plan is the fundamental responsibility of a pilot, therefore to the extent practical alpha numeric or arbitrary symbology can be eliminated. Since this information requires mental integration which is distracting the pilot from the primary task of constant intuitive spatial awareness. In a transport circumstance, occasional pop-up information reflecting graphic values as opposed to alphanumeric or arbitrary symbology which is phase of flight dependent is acceptable to a pilot from a spatial awareness point of view. I have a video that will be shown in a side room.

Doug Trumbull, Entertainment Design Workshop: I have an aviation point of view. I was a photographic effect supervisor on the 2001 Space Odyssey - 70mm cinerama. On this giant 90-foot curved screen you felt like you were in the movie. This experience at a young age altered my interest in immersive experiences. I have recently been participating in digital revolution. We have been doing this in the movie industry with computer graphics. Daily we are superimposing real images of real life situations with computer graphics and merging them together seamlessly. A recent project I worked on was an adaptation of a flight simulator in the Universal Studios ride--Back to the Future. This was a flight simulator for 8 people surrounded by an 80-foot hemispheric screen with extremely high resolution displays. It is an extremely powerful immersive experience. The epiphany I had while working on the Back to the Future ride by presenting anyone with hemispherical display with image that replicates human views. It is a very powerful human stimuli and responses. I have always been interested in continuing to develop this technology. Over the last 3 years I have been with IMAX. Been developing advanced 3-D high quality system in domes and flight screens. Also been putting IMAX 3-D cameras on shuttle for the last 4 years. Familiar with aerospace business entertainment. Developing six passenger simulation entertainment project which will have real-time graphics, a hemispherical display with electromagnetically actuated motion that is quite powerful. Our business everyday is just do it. We don't have the FAA to tell us we have a good idea. We can buy a computer and component and put it together. We just hit the ground running. To help pilots immediately, we need to be able to cut through the bureaucratic red tape. We are regularly using SGI and Unix machines as well as Windows NT-platforms. I believe from my point of view that what pilots need in order to have what Phil says as intuitive interface is an image displayed which replicates the reality. He doesn't need an interpretation. If CFIT occurs because of loss of visibility, i.e. he does not see out the window. It seems natural to place a view out the window, not in front of the display. Most of this needs to be implemented into retrofit. I am familiar with projection technology in existence and some in development at Honeywell. I feel strongly that I haven't seen anything that you could retrofit into an existing fight deck. You can do a HUD, but a wide-field display is another challenge. The only solution I know so far is to encourage Microvision's work. I feel like there is a chance that this new laser-based retinal injection concept which can deliver a very high resolution, wide view display without intruding on cockpit or pilot. It is by virtue a head-mount display which only weights a few ounces. Doesn't intrude on comfort. This may be the answer to getting displays up and running in a cockpit very quickly. Graphical systems to display terrain, weather, highways in the sky and flight path. I also know in the world of computer graphics - stereoscopic perception gives whole new awareness with 10-fold increase in perception and awareness. Can be achieved with laser based HMD. A.J. Yarmie described those technologies. I think eyes out is the way to go. Also hyperstereo - where you increase from normal human interocular distance of 2 inches to any distance you want which allows you to extend way out.

Question/Comment: Mike F. of United Airlines. (addressing Corwin from Honeywell) United airlines is very interested in CFIT. We are extremely interested. United Airlines is the first airline who voluntarily committed to installing enhanced GPWS on its entire fleet. United Airlines has very vigorous training that stresses the avoidance of CFIT occurrences and procedures to clear terrain. We are acutely aware of CFIT problems and we put all the new technology in our airplanes and train to avoid CFIT problems. What UAL is saying is we don't see any technology that would improve our CFIT avoidance procedures anymore than we have done.

Question/Comment: George Kaseote of FAA. One gentleman said apply now because certification process takes so long. I don't agree. A lot of times people submit applications without the data which means we are stopped.

Tom Leard: The point made by a panel member is of constantly carving new ground: display integration, display processing, information processing. That data needs to be submitted at an early stage with meetings way up front with appropriate FAA engineering offices and both parties recognizing roadmap to certification. It follows through certification. It follows regular updates of FAA team. In the field on human-centered design, the data that's taken may be a collection of experienced cross-trained pilots to evaluate what's put together into the process - that takes time. I think FAA is very interested in cooperating but answers aren't written in a book.

Bill Corwin: I said 2 provocative things. First, let's go back to the comment made by the gentleman from United. No offense was meant. What problem and how are we going to solve...agreed. Honeywell about 4-5 years ago in pursuit of enhanced situation awareness system was struggling with issues that Allied Signal has successfully struggled with. Honeywell was left with a situation where we had concepts in place but we felt that it wasn't in the best interest to invest time in terrain database issue 5 years ago because of the certification hurdle. Internal decision bases on previous experience with the certification process.

Question/Comment: Jim. I want to reiterate what George Boucek was saying. What requirements? Our we letting technology drive the requirements? This concept has been around 50 years and why aren't we using it now. We realize technology doesn't meet the requirements but we haven't addressed what the requirements are: accuracy, redundancy, etc. Once these are defined and we know the requirements we can say we have the direct input on benefits. In lower altitudes, definite benefit for such a system. In getting those guys out of airspace and letting airlines operate more efficiently that would answer the question is there a direct benefit.

George Boucek: Thanks Jim, but we have to go farther. In order for us to sell the idea with customer or internal management, we can't use the words "I believe" or "pilot believes". We have to be data driven. We have to generate data that shows benefit of technology or functionality that we are trying to apply. Opinion that we may have vs. opinion management or buyer may have. If comes down to opinion vs. opinion then management and bean counters win.

Tom Leard: Regarding technology driven. An example: A controversial piece of technology with many cockpits is the flight management system. We were so desperate as aviation was expanding with the jet age to get around carrying a navigator around. We put in latitude and longitude information in a self-contained box. Game for doing that because it allowed us to get started. We were game to use the navigators accountant device because it cut down on economic expense. Now we are looking for another solution because was not a perfect solution.

Phil Brooks: Amplify what George has said. The reason (for the system) in the airplane is for operational expedience and efficiencies. Under the context of just do it there are two hurdles: Certification and Justification. We have to be able to develop cogent argument which gets brought to those who make the business decisions. Make your business a better bottom-line proposition. That is what I need to take with me. I suggest in addition to prototyping, certification, and documentation there should also be cost argument development. Dave Foyle's information is what we need to jump that hurdle.

Question/Comment: Requirements vs. goals when designing aircraft. I work on B-2. You set up parameters called requirements. When we look at safety there were specific requirements and safety for the B-2. What are the requirements from Boeing for designing a plane for safety? Statistics show that CFIT is the number one thing - which may or may not be true. Any specific numbers that you say here is our safety requirement? From an economic point of view - Any business operates given this is my requirement. Without requirement it is come and catch as you can. Has Boeing put out a requirements list for safety?

George Boucek: Bottom line requirement for design is don't let system be less safe. The goal is to make it more safe. The goal is anything you do in the flight deck is done with a safer system in mind. What we look at is what functionally we can demonstrate that will make the system safer.

Question/Comment: 20 years ago I worked statistics and safety. It has come down. I started looking recently because I lost a friend. If you use a goal that we don't degrade safety--is that why for 20 years there has been no improvement in safety?

George Boucek: I disagree that there has not been improvement in safety. In fact, in the last 20 years it has improved greatly. It has improved in areas of mechanical systems especially and air traffic systems. That is why the US domestic system is so much safer than other places in the world.

Question/Comment: In the last 16 or 17 years, fatalities have stayed constant. That is a fact those improvements occur before most people have been involved.

Question/Comment: Is your question - We have this goal to increase safety. But George says we can not do without requirements. Doesn't the question get to be--how do we take this goal and from this derive the series of requirements?

Question/Comment: What are present requirements for safety? And if there are none shouldn't there be some? And who makes them?

Tom Leard: That is why we are here. Al Gore Commission, looking at industry, reflecting on statistics show it is a mechanism to provide incentive to go do something about flattened curve. This NASA process is an attempt to go do something about the curve that has flattened out. Have national goal established as an ambitious national endeavor. Our challenge is to influence all manufacturers to do something about making it happen.

George Boucek: A system that has 10K, 20K existing airplanes has a lot of inertia. Look at CFIT accidents between glass cockpits and analog cockpits and there's a difference and improvement. It is not the lack of putting safety requirements, but identify areas in which we can improve safety and crew performance. Identify those and what we can do to do that and then accept safety benefits we get from it.

Question/Comment: Glass cockpit statistics. Shouldn't one thing be set up quickly? At the beginning you brought up goals of Gore commission and said that's not a requirement. Why can't there be requirements (like stress on the hull) and set this up as a requirement? Why can't we make that a requirement on the design of the aircraft?

George Boucek: Give me the metric and I'll set up. Give me the metric for the requirement.

Question/Comment: There is some metric on this is that we have seen several test results of synthetic vision flying – flying on a highway. Phil has results that George Hoover did. Germans did good job of testing synthetic vision and it works. Barrows' showed tracks that they flew but it's no design parameter, but a performance parameter that has been measured. We know there is something that works. There is an integration. The goal is to improve safety but we need design requirements. Germans have done a lot of work trying to find out what the requirements are through studies over the years. They evolve their requirements out of tests. There is a difference, there is a goal (which is not a requirement). A requirement falls out of design criteria. You can have 100K ideas to increase flight safety and they could be resolved into requirements - one could be synthetic vision. But the goal is flight safety.

Question/Comment: I want to add some thought about difference between synthetic vision and existing enhanced GPWS. By chance, I was looking at an FAA report by human factors team on interface between human crews and modern flight deck. If you go to executive summary of requirements it says the FAA should encourage the aviation industry t develop and implement new concepts to provide terrain awareness. Crews would be glad to have terrain information while enroute so they know where to go when all engines stop. Difference between EGPWS and what can be implemented if we had whole world terrain depiction on aircraft. This is one of the things required on FAA report.

Question/Comment: What can really6 mess up the measurement Eastern accident over the Everglades. If you have synthetic vision up there it wouldn't work. You still have .03 sitting out there when you have an accident. Hard at those low numbers to get a measurement back out of it to say something is going to work or not. Direct to cost effectiveness and get enhanced awareness from that...

George Boucek: What Phil said is that one of the key elements that come out of NASA/Industry teamed work is the data that would show us what effect of putting the technology in there. If I have function to land at lower minimums at runways (fields) ends that are not certified, Can I show that pilots can do that task? And what would it buy me if I did get that function? If I can generate those 2 pieces of data then I can convince someone to put function onto an airplane.

Question/Comment: Mike Snow of Air Force Research Lab. In the human factors community we have a number of measures of situation awareness. I would contend that what we are trying to do in simulators is put pilot in situations where ground impacts are much more likely and correlate SA measures with ground impacts. Show decrease SA is greatly correlated with ground impacts. Then, hopefully in flight test show that a system that greatly improves SA would then greatly reduce ground impact.

Phil Brooks: Mike I take that as an observation. I didn't want to interrupt you. I think there are two points to Bill and George. George's amplification of Bill's comments. I believe the success or failure in terms of industry is quite literally where the rubber meets the road. If we can increase the acceptance rate of aircraft onto the runways and all the efficiencies achieved operationally that result from what Bill says that the safety follows. The second point about Bill's comment about Eastern flight relates to George Hoover's research. I think that based on my investigation...[showed chart of first aviation factors program]....in case of Eastern if we go to motion parallax...human eye naturally goes there by evolution ....eye goes to target, if on 3-d display in the cockpit if you saw motion...your eye would catch in a cockpit. Important thing regarding synthetic vision – Impact site of Cali crash - our crew on that airplane made erroneous turn to East and corrected pack to SW to intercept their course. Unfortunately, there was intervening terrain. First Officer leveled wings and executed GPWS maneuver. If that airplane had had some vertical guidance about ridgeline available in cockpit, the pilots would have continued turn for a few seconds and would of slid off shoulder of that ridge. That was crucial information that was lacking.

Question/Comment: Another subtle safety implication to displays not mentioned is as we transit more and more across state boundaries--we will have pilots flying in unfamiliar territory. Needs to be considered another aspect of increased safety.

Panel: Excellent point. Being on the road. It is nice when you can stay someplace more than one day in a row. If terrain were accurate with margins built into Instrument Approach System, that may make a difference in those unfamiliar places that we don't have to go to. Any other comments?

Russ Parrish: Thank you panel.

PANEL FOUR: Databases

Chair: Ron Bolton (NOAA)
Members: George Chang, Mario Chuliver, Wolgang Kubbat, Bob Severino

Ron Bolton: I put in documentation about different resolutions and accuracies by using a strawman for obstacles in terrain that will be held in Montreal, Canada.

Bob Severino: Covered points in last presentation to reconcile accuracy for new test data. There is about a one year processing where data will be post-processed.

Mario Chuliver: I work with ADR, Inc. Corp. which is part of General Dynamics Electronic (GDE) systems. We were purchased from GDE a year ago. ADR has been on opposite sides of the spectrum. We have been talking about the database in the area of level one and level two. We have been working in the area of sub-detailed area five. Producing land bases for civil engineering and sub linear/subfoot. You can obtain accuracy if willing to spend money to obtain. Our interest in participating has been to gather an idea from all of you in regards to what exactly is quality and accuracy of the data that you deem necessary. Is it that the consensus that we need data in the area of +/- ...2 meters vertically. I would like to leave this meeting with an idea of where the whole industry is going. In the mid 1980's we were involved in the stuff and analysis of airport extraction which was not by any regulatory agency of the US, but in all cases by civil engineers, but engaged by love for airport management. We worked out a mathematical model to produce this kind of information. We felt that the type of approach for what we are trying to achieve now was produced in approximately 15 airports. Most were county level airports, however we did study for one of the runways in Laguardia, Dover Air Force Base and others. Some examples employed photogrammetric methods which was the most important study that we carried out. This was the type of information that we provided. We used digital orthoplots, used vector...facility wide GIS. The process was carried out by acquiring leaf-on aerial photography. We provided GPS to area control in order to support land base. In several cases we set up monumentation to be left in facilities including the airspace studies and transition and chronicle surfaces as well as horizontal surfaces. Some of you may be familiar with the different surfaces to be studied, some have distinct weight, length and ...[showed chart]...magnitude of the intrusion. The primary surface of the boundaries is that it is a rectangle. The other parameters show where they begin and end. Down to accuracies one foot vertical for spot elevations. [showed chart] These were the items measured: buildings, trees, and powerlines--anything manmade and suspected of intrusion in an approached surface. This is a chart that can be expected with different types of imagery. They have the capability of yielding in areas of 3"...which available to civilian community within 6 months. The company has launched a satellite with 3M ground (been out for a month now). In a couple months there will be another one. With a one meter resolution in space imagery [showed chart]. What is runway studied and approach surface, etc.? This was the type of study that we produced This kind of experience could be applied to the type of endeavor that we are working at now. New tools to do this type of work. Technology becomes available. What you mention in regards to digital camera is something we are interested in. That in a nutshell is what we have been doing. I would like to see resolution in order to satisfy your requirements.

Wolfgang Kubbat: I have a 30 year background in aerospace and in issues there were control theory and safety. In industry I ...a control ...supersonically flying disable controlled. Control theory in order to stabilize and safety. Then I had a love with helicopters so I flew digitally controlled. I then inherited the tornado problem--tornado is a low level flying aircraft being flown by the Air Force of Italy, Great Britain, and Germany. It is in serious production already. I left industry after I designed a control system for...issues control system theory, highly agile aircraft and safety. Referring back to the tornado, it is an airplane with an automated terrain following system. I admire those people who sit in the F-111 and don't know what the system is doing and they go up and down. It is visualization. I accepted an offer to be in charge of Institute of Flight Technology. It was a minimum obligation to teach 8 hours. I told my wife I could teach singing--she said no. What kept popping up in my mind was safety. You really have to do something with better and faster information...another clock...glass cockpit didn't have much they need pre-processed information and...Have close ..VDO...let's visualize the outside world and start with picture of primary flight display to overcome major problem of today's CFIT. Give primary flight display to pilot and added...the pilot needed more to do. One issue about taxiing--if complete display philosophy which can be retrofitted or installed in new airplanes. I started to do the job as complete as possible, so we got engaged in the database problem. We converted this database into a WGS84 but did not start test flying without validating. We built a DPS and GPS which was haste correction and are in the area better than 10 cm. We did not flight test without calibrating, however the purpose of this meeting I will say I am a user looking at the data problem rather than...detailed speech later from ??? Again, the safety issue is very overwhelming. We are talking safety in terms of handling the database.

George Chang: I am George Change and what is in my mind right now is sets of aviation data information from three professionals. I finished Engineering school in the mid 1960's and went to Boeing. I then went on to work for the Navy and two universities teaching. I spent 2 years with the FAA HQ. I took an early retirement and am now an independent consultant. I want to shed light on some things. You've learned a lot in this room and elsewhere. The aerospace world is complex, whatever we technologists do database is included. We need to keep in mind that we need to satisfy and get buy-in from two parties (the pilot and aircraft controller). How do we start? You might ask what kind of standards are in all this. Standards for aeronautical information --you can pull through operation requirements and existing. You can define operation requirements based on mission. Is it nearly CFIT?. Defining a mission you can do one at a time and get some work. You take care of human factors. You do all kinds of things then you may want to say I do all these things. Is it affordable and cost effective especially for the same theory. The bottom line is not because they love something, but finally I suggest that you might have better understanding of how FAA works--the organization, people, culture a lot of that misunderstanding is hurting people's morale.. The FAA has many functions: 1) to promote aviation, 2) provide...3) certification of air equipment , 4) provide flight standards and 5) security mission. Finally I would like to venture to suggest for consideration that we can use elements of all these technologies to formulate business strategies.

Bob Sutton: I help the Program Office. It really gets to the issue when put mission of Orbiter...Alaska is missing. Anybody know what is going on with getting Alaska information? I ask the question because somewhere between...happen in that state. If our goal is 80-percent we need to know Alaska.

Panel: There are now a number of efforts taking...technology and using airplanes to take those sensors and scan parts of states. What I don't know is if the scientific community has approached sources of funding approaching Alaska and the FAA (not only from space but learjets).

Panel: In area of commercial there are no blind areas on that type of coverage. It will come down and become immediately useful. For example without the need for additional ground control or other support you can create accurate DEM from stereo-imagery so there would be another possible source for information.

Ron Bolton: There are some 8,000 procedures which I have in my books, 90-percent of which are FMS approaches that deviate from minor to major ways from the approach. We don't want to do this in this database, whatever we decide to do to should help the pilots. One suggestion I have is since this is not to land aircraft per say, but to aid the pilot not to go into CFIT, look at the different phases of flight and resolutions. A lot of you have studied the problem and I would like to discuss what the panel and you feel. We don't have to have just one database. If you're going to fly airplanes using a database to prevent CFIT and get general information. Is this a good enough strawman to get us started?

Jorg Baker, Free Flight: Do you have a synthetic vision display and are using it? I want to let Bob know there is data available for Alaska. It is the same stuff we are using in the U.S. which you will see tomorrow. We can cover the whole planet with 30 arc-sec data on one CD-ROM and have their space. You have 15 minute data which may be accurate for CFIT, but seems thin to me. I may want to know roughly what the terrain is. In the terminal area I don't see unless there's some weird terrain on the airport. We are planning on using a 6 second demonstration and as you get higher 15 sec and ideally in route below 10,000 feet we would lose speed limit. If above 18,000 feet it would go to 5 minute data.

Tom Leard, Honeywell: Interested to hear two approaches as to what is the right amount. How accurate? It's pretty impressive that we think with 30 arc-sec data.

Jorg Baker: Can do that with just over 5MB. Flying across the ocean may be more interesting and inexpensive for us.

Tom Leard: How accurate is the tradeoff? How readily is it? How much space and memory is there to carry around?

Panel: We'll have to see what happens as a result from the Montreal Conference.

Ron Bolton: Do you use the same source?

Panel: No. We probably need to think of multiple ways to do this. For a week I looked at all data from 300CPU's. The point is that it is a considerable job to process all the data just to get to a resolution of 15x15. It's a considerable job to go up in resolution and talk about satellite collectors. Like Bob mentioned, resolution is an important issue.

Comment: Another piece of metric is world wide operation vs. one or none. We see remnants in our navigation. I'll take it that way so the crew don't have to change over.

Ron Bolton: That is a valid consideration. We have to make it easy.

Bob Severino: The overarching objectives is to establish a database, a focus area and a clearing house. The idea is on developers who have different interest.

Ron Bolton: Accuracy and update are problems. We know there are reliability problems that's why we can use the strawman for accuracy.

??? : It is very commendable and important to feel there is to much of a push for a final approach and all the way through CAT 1, 2, and 3. We push beyond what it can do. Afraid we are locked in a box if we think we should do taxiing through the gate. I hope the synthetic vision effort does not blind itself.

Ron Bolton: It would not be that expensive. I left literature that would let you survey in a few hours all airports and be accurate to about a 1/2 a foot. The database needs to be updated. Can not assume that as gross as they are that they keep updating them every six months. They are obstacles that are changing. You all should understand that fantastic changes every cycle. The 56-day cycle is well thought out.

Wolfgang Kubbat: When I am listening to this discussion I sometimes get lost. I think somebody has a goal here to produce a super perfect database covering all issues in the world. I think the world is different. If for instance an airline wants to establish a new road. Somewhere in the world to Pedro??? in Russia and Pedro??? does not have good database--what would I do if I promised myself this is profitable route. I would go to Pedro??? and take my GPS, star shooting equipment and would produce my own database. I could calibrate. If you think you have promised yourself that there is an airport that I can make service to and gain profit at, not much money or risk to extend database to an accuracy which you can land on under category 3 in near future. This is what I experienced with the flight test we did. I was lost in this discussion because no one in my opinion would land in a spot that he has never been without surveying the area or checking the integrity of the data.

George Chang: I will be brief. With all due respect for the panel chairman and with a flight standards background in mind. I would like to suggest that these numbers on charts deserve much more scrutiny. I disagree with many, but not all the numbers.

Comment: Another part or side is depending how the database is incorporated in the flight management system or autopilot system. Depending if you want to shoot approaches with it. You have to certify it to be fail operational. This means ten to the minus nine or ten to the minus 12. You have to make data link operational. Thinking about databases somewhere down you have to be certified if you want to fly with it ten to the minus ten to ten to the minus twelve. Depends on approaches you want to do. Can be a very huge problem. This should be how the database is incorporated into flight management or autopilot system. Not only does the data have to be good but fail-safe. It is much bigger problem than putting to one meter or two meters or things like that.

Russ Parrish: Ron, are those proposed standard available in the back of the room:

Ron Bolton: Yes, I have given those to Lynda. I want to say one thing that you may think these charts are off-the-wall. The figures are kind of off-the-wall, but the references and ideas for needing to do standards were developed after these particular readings . There is one where the two references are to George Boucek and representatives from the Volpe Transportation Center. The effort was to start a discussion. Everybody has gone around in circles. It hits me very hard that the last gentleman who brought up certification. That is a very important part. As producer of charts, for me to think there are literally hundreds and hundreds of flight management systems really not flown by the FAA - leaves me to say I have great concerns about this kind of data because people might certify the system and not the data. That would be so dangerous. To give you an idea, I turned down publishing a procedure (which is probably illegal for me to do) because the NDB that came in surveyed was 800 feet off and 400 feet to the left on the runway – right on a road. It was misplaced. No sure way with GPS or any other system that everything is right. The only thing is if somebody should check that data (an authority) and certify that it is safe data. If we go in throwing data around we will be in serious problems very quickly. Thank goodness the FAA flies the rest. I am concerned that they are not flying the FMSs even though competent people produce them. The point is anyone can make a mistake and somebody should certify the data. When we go the for the next step forward into visualization which will really help not make mistakes, situation awareness will be enhanced at no hand, even if we do a gross system. I think the data must be checked.

PANEL 5: Advanced Vision and Sensor Technology Session

Chair: Thomas Campbell
Members: Ron Bolton, Richard Burne, Malcolm Burgess, Mike Frank, Richard Kerr, Paul Leckman, Dutch Neilson, Mike Norman, Vic Norris, Alberto Ortiz, Merit Shoucri, Peter Symosek, Dick Zeylmaker

Thomas G. Campbell, NASA Langley: The panel consists of participants who have experience in Sensors, Sensors Fusion, Flight Operations, and Data. Approach of what we want to take on during the panel session is to address the main question what is the role of sensor technology in the synthetic vision element of the aviation safety program.

Mike Frank, United Airlines: I am from the office of Flight Operations in Chicago. I will be talking about the Airlines view on this technology. Technology - we are not building anything we are your customer. The airlines buy this stuff (technology). I will give you a quick insight on how we buy this stuff – our acquisition process. Process on buying this technology - addressing user requirements. Helicopter community has different requirements. We need to make a business case in the airline business for everything we do. I review a lot of things bought for the airlines. Cheapest and most efficient way is what we look at. Pilot associations (unions) are not customers and do not own a checkbook but the airlines do and it has to go through a financial department to get approved. Pilot unions must provide more of a business case than an emotional case to get SV technology on the airplane. New technology does not produce revenue but may save cost. It is hard for a financial person to understand this. Difficult to justify cost-savings but easier to justify revenue generation. Cost savings are not real and they cannot see this. Just because we justify this but that doesn't mean we are going to buy it. Airlines come out with a capital budget every year for improvements. And even if we justify synthetic vision for collision and avoidance (the cost less than the return) and we got approval for the capital budget. This does not mean we are going to spend the money on that because every bit of money in the capital budget has to compete with some other organization or division in the company. Capital budget fluctuates. If fuel costs are low, capital budget is big and vice versa. We have to make a very good business case for this. Not just acquisition costs, but there are other costs associated with obtaining a new piece of equipment. Here's a chart for cases of dead-end technologies.
Dead-End Technologies:
MLS (Microwave Landing System): FAA spent billions but could not make a business case for this.
ESAS (Enhanced Situational Awareness Systems)
ELS (Electronic Library System)
ACAS (Aircraft Collision and Avoidance), **BCAS** (Beacon Collision and Avoidance), **TCAS** (Traffic Collision and Avoidance) systems: To solve problem of mid-air collision, government working on a program (ACAS, BCAS, TCAS). The name changed over the years, but still working the same problem – preventing mid-air collisions.

TCAS is on airplanes because it was mandated in 1988. We are the safest transportation mode - fewer fatalities per accident mile. Hard to quantify safety devices - this is why

TCAS had to be legislated. Safety does not sell - legislation only required that large air carriers equip. The commuters and the cargo carriers were not required to put on this safety device. Last year the commuter industry was required to put on TCAS but they did not do it voluntarily. Safety has to be legislated on the airplane to install safety devices. So what does not sell - low altitude flying through canyons and we don't do that. There is a FAR that says you cannot fly below 1000 ft in congested areas (500 ft in uncongested areas) and you should not be close to the ground. Talked about database systems whose sole purpose and intent is to avoid CFIT by presenting mountains. This is a safety issue and cannot make a business case for this. May end up in the dead-end issues. NASA has a lot of good programs, dollars and people and good potential for us and the community if we can get everyone focused in the right direction. Someone earlier from Honeywell mentioned about the Cat II approaches would we buy that? 1000 percent correct, but he's the only one that mentioned Cat II approaches. Cat II is a problem in the airline industry. If we can get to airports in low weather visibility conditions then we can enhance our throughput and increase our revenue and this is a big benefit for the airlines. No one except this gentleman has mentioned putting terrain databases in the airplanes so we can go to Cat II minimums at all airports and no one thinks this is a problem. For instance - Dulles airport has 6 runway ends and 5 ILS approaches and one Cat II/III approach. And as long as the weather is good we are pumping 110 airplanes through that airport an hour but below Cat I minimums the throughput rate drops to 25 airplanes an hour (75% capacity reduction). Throughput is a problem when the weather goes down. If we had something that enables us to operate in IFR like we do in VFR and keep the throughput up, this is a cash benefit for the airlines. How does that fit in what we are doing here? He shows a chart on the results of NLR study that was done earlier around 1988. NLR study said that: 1) 75% of aircraft involved in CFIT accidents were not equipped with GPS, 2) 70% occurred during the approach and descent phase, 3) 20% occurred enroute, 4) 60% of the approach phase accidents are to non-precision approaches (no vertical guidance), 5) 24% of these non-precision approaches were VOR/DMEs, 6) 90 percent of the accidents occurred within15 miles of the airport and 7) 40% did not involve significant terrain. If you do not address the approach and landing scenario, you are not addressing the CFIT problem. If you do address the landing phase and can operate at airports in low visibility weather. Then there is an argument for the financial department. If NASA address this problem on the issue of the CFIT arguments then maybe the financial department can see this to increase throughput, etc. Give a way for a good business case to sell to their management. Not NASA's responsibility for airlines to make money - but I need something new in technology to sell to them. What sells? We need to get to Cat II/III approaches at every airport. Curved emerging approaches - we would like to do those by allowing us to modify the TERP procedures (Terminal Instrument Approach Procedures). TERPs draw trapezoids to prevent airplanes from flying into objects on the ground. Takes error in navigation signal to determine size of trapezoids. Terrain database might enable us to reduce the TERPs criteria so that we can increase our capacity. May need some fusion technology later down the road. Need to look at the landing scenario with a good technology focus within 15 miles of the airport. Keep the cost low. I have a concern that if the display is there all the time the pilots will look at display all the time and not look outside the window - too much information overload. And possibly integrate with other sensors.

Paul Leckman, Boeing: We at Boeing have pointed out several times the starting point system like this is requirements and the people that are using it is the airlines. We need to know what they want before we even start out. When we know this then we can start out at the right place. ESAS - That program was at a dead-end because of the financial justification as he was saying. How HUD's got on the airplanes basically was because they had to be justified by the airlines on an economic basis. Each airline is a little bit different. They know best what their financial advantages are for various types of equipment. They can weigh if that technology is worth it and when they do decide what they want then the requirements are laid down and then we shoot at those. This panel was aimed at sensors and CFIT. So, I tried to zero in on that first and I think of how sensors might be used in CFIT. I think of the existing enhanced ground prox and database as Don Bateman said was perhaps in some cases suspect as well as he knows this area where he doesn't have good terrain data and what he has may not be exactly right. I think sensors and a good enhanced ground prox system checks the radio altimeters and what they should be reading knowing your position and the height of the terrain, and flag captures the areas where they disagree into any significant amount. In the future, I think if radar can be used to flag areas where there are disparities and terrain databases where the radar indicates that the database may not be correct. That needs to be flagged and logged so that those discrepancies can be resolved. I think those are two ways that sensors can play role in CFIT. As time passes our database integrity gets improved. When you talk about approaches and sensors, I think it is good to have two dissimilar navigation solutions because if you lose one you still have the ability to navigate by another independent means. Those things like enhanced vision is really only up to the airline to figure out whether this is economically viable or not. There is some merit to having an airline in control of its own destiny in terms of approaches if they are to be as autonomous as possible. I think there is some financial benefit to be gained there. Like Mike was saying when we get the numbers down (category minimums) and reduce the uncertainty as to the obstacles and terrain heights in an area around the airport on the approach. You can survey the area quite nicely with a laser system, which has good accuracy. Or at least in the area where the approaches are being made. Having flown several planes with synthetic vision myself, I feel that we have to be careful giving the pilot displays that are in any way ambiguous and perhaps difficult to interrupt because of the stress of low approaches and the small amount of time you have to analyze what you are looking at.

Richard Burne, Allied Signal: Response to some of the comments that were made in regards to the database and the enhanced ground prox warning system.

Don Bateman has the expertise of what is in the enhanced ground prox database and what's not in the database. I'm addressing what is not in the database and it is a big concern to me. Obviously, you have multiple sources of error when you are dealing with database and onboard sensors. Some of the concerns raised from my customers both from a cost as well as an implementation certification issue. We have taken an approach of using the onboard systems. Enhanced ground prox will be onboard but there is already a weather radar system onboard. What we have done is taken that weather radar and correlate it to the database. [He shows charts on radar image of the terrain and correlated database] We intend to move into this direction to provide the validation of the database. We think this will provide us with enhanced safety margins by the database where it has holes and not being valid. The database will be correct for the pilot. We will have this in the background and not be seen by the pilot. A sensor combined with a database is almost a necessity especially if the database is going to be used as a navigation aid. This concerns us to have the database for a navigation aid. As far as providing alert or a warning to the pilot, and not to be used as a navigation aid, the enhanced ground prox warning system does that for us today.

Merit Shoucri, TRW: TRW is involved in developing passive millimeter wave as a potential EVS sensor. Comments will be generic to sensors and more specific to the objective of the workshop that NASA is soliciting industry feedback. I prepared three charts. The user community is usually illiterate to sensors or partially illiterate as far as sensors is concerned. The user is us, anybody involved in EVS, FAA, and those that have different understanding depending on their degree of involvement with sensors of what it can do and what it can't do. Very little understanding on what sensors do. You might disagree but just listen to me. Whether the sensors is coming from real-time or a database, still the data always comes from a sensor, so this is always back to a sensor issue. I see a great need to understand sensors. While airlines are concerned with economics, airframers addressing backlogs and trying to push aircraft out of the assembly line, and with an R & D at a minimum with industry, the person working the database is not necessarily working the EVS sensor or the company working EVS sensor is not working the database or the other sensor. There has to be an enlightened body somewhere in the US that is working the R&D part as opposed to product. I propose that NASA should take credit for a great deal of this function. If we set goals, then what is the requirements for it (to develop SV technology)?. I have not seen a set of requirements and the reason for that concern we jump to one approach to another. I see that a thrust for SVS should clearly look at various architectures depending on rotorcraft, general aviation, business, or transport. There are a lot of architectures that can be implemented there. So that if it is a sensor or a database or a combination of both we need to come to have some requirements. To solve CFIT and visibility induced errors, we can take a terrain database approach which is a monocular view. Or we can take a 2-dimensional view by using sensors solution with database solution. Or we can take a 3-dimensional solution (database, sensor, system requirements) by looking at issues of human factors, of integrity, reliability, redundancy. Before we go too far in databases, make sure that your 9 digit or 5 digit is doable. Sensors is where the thrust needs to focus on. NASA needs to be more ambitious than just looking at the terrain database. Many architectures, technology trades and evaluation, concepts and human factors that should be addressed in Synthetic Vision NRA.

Mike Norman, Boeing: Lesson here that should be learned is when you talk about a new system or more information in the cockpit for the crew I think you should be more suspect before putting that in. This is not saying you can't put it in but you better do your homework carefully before you put it in. You cannot ignore infra-structures costs, certification costs and return of investment for the ultimate customer. We are not in the safety business. Safety is an adjunct to our business. The safest thing to do is not to fly. While we build and fly safe airplanes, the main motive of Boeing and the motive of United Airlines is make the money for our shareholders. You cannot ignore that when you are talking systems that you have to market and sell on a widespread basis. I think we need to decide what we need to do with this SV system. In some ways it is unfortunate that we title ourselves around a system and not a process or a function. We ignore that function and go straight to the system. I don't feel that it takes years to do this. We just need to sit down and decide what we want to do with it. I suggest at candidates to look at is terrain awareness as distinguished from terrain clearance enhancement. I feel they are two separate missions. Autonomous manual control in Cat II or III in degraded weather conditions is also a candidate. After deciding this we need specifics as to what mission have to do and we need metrics to decide if we have achieved those missions. Then we are ready to catalog the technologies that we have been hearing and decide what might be appropriate for the task and what advantages are more pertinent. Also look at some of the disadvantages. Augment that safety enhancements can be good business but make sure you do not ignore business when you talk about safety enhancements.

Panel: What constitutes a successful team? Industry teams to invite NASA to participate because you could not do it alone. Key components of a successful team is the users and system engineer. To get requirement straight, we need to understand the reliability requirements, integrity requirements in turn to response to the users need. Technologist is key component of the team and manufacturers are also important part of the team and so is project management. Where does the project management come from in these teams? Is the industry looking at NASA to provide that management or is NASA looking at industry to provide that management? I feel that there is a word missing out of project management that maybe it is leadership and where is that leadership going to come from? I feel for a team to be successful that it needs strong leadership, and a very strong program management. I feel that if we cannot answer these questions that we have not accomplished our purpose.

Tom Campbell: As far as program management what would industry like to see happen? [no response given.]

Carrie Walker: The process is we are going to put out a draft NRA. You will have the opportunity to respond to that draft and say we feel we have something to offer that we can not propose with these words in the NRA. So we are asking industry to help us with our definition and requirements of the program. We have expanded our definition of the NRA that we have expected to put out through the education process that these couple of workshops have given us. In regards to the project management, Mike Lewis outlined the first day the organization of the Safety Office and their elements. Safety Office is the integrator of those elements. We expect for the industry teams that are awarded to manage their projects as they successfully manage all their projects. And to look to the Safety Office for the overall integration of the elements that need to be communicated and integrated.

Comment: Would this be the job of the Safety Office taking it into the marketplace, certifying and implementing and supporting it?

Carrie Walker: No.

Mike Lewis: We have some funds-not a whole lot of money- but there is a lot of good things going on here in technology and applications. We are putting some money into this program. Long term R&D in a healthy kind of way. We are not going to make it for both the safety program goal and for the potential as you see in this room and the outside of this room if this NASA program is 80-90-100% of the work that's going on out there in SV technology. NASA's role will be a catalyst and we will try to do the right governmental things from a NASA perspective. There will be good ideas that NASA will not be able to fund. If people think their ideas are good, they will work to proceed forward with their ideas anyway. NASA will work with the FAA in setting up rulemaking or certification criteria or system performance criteria which will apply to that that work independently done as well as the work supported in the NRA. NASA has resources that try to bring together an integrated product for evaluation, demonstration, test in our 757 aircraft, and on simulations. No way is NASA going to pay implementation into the fleet or systems integration of a certified product into existing airplanes and so forth. This is a non-NASA role. This part of the program (SV) has great potential to pay for itself. Forget the safety benefit - can pay for itself on how planes can operate and fly. I hope that you guys are competing against each other to provide that capability because it is lucrative. I hope that we can see that this might happen before it would.

Panel: A successful team has got to embrace the objectives upfront that is to reduce the accident rate by a finite amount to be able to have an established metric and a successful management team will allow us to get there and measure the result. These are all the things that Mike Lewis mentioned that NASA is not responsible for and that industry must be responsible for. What is the scope of a successful team and proposal?

Mike Lewis: There are 3 metrics – 1) Technology Readiness Level that NASA is involved with and is often the major participant in. Other people do their own R&D and do technology readiness on their own. There is also an 2) Implementation Readiness Level that is a parallel activity. NASA's role is directly involved in the Technology Readiness Level and in supporting the FAA in the Implementation Readiness Level. Implementation readiness level is mostly a FAA job plus NASA plus industry. Industry's role is to look at cost benefits of system, buy it, apply it, and implement it into the fleet. Only when 100% of the fleet is equipped will you realize the safety benefit of a particular product or technology. NASA will think about the whole process and pull it all the way through and establish a safety program portfolio. This arena is fertile enough to have multiple groups team together to do it better, cheaper, and faster.

Vic Norris: We in industry think NASA should consider not only the database technology, Synthetic Vision, but bring that problem all the way in (initial approach to landing) and blend with sensors. NASA needs to consider total systems aspect.

Ron Bolton: Approach phase of flight is where we need to concentrate. We are changing procedures at the rate of 1,500 procedures every 56 day instrument cycle. We really need to make plans soon. I think research effort is necessary - needs tighter leadership role. We can solve the research effort with the database in terms of terrain and obstacles. The technology is out there with laser technology devices and digital image cameras to get the terrain in the last 5-15 miles of the airport. Don't look at the past and not the future. We are changing procedures very rapidly. We are changing procedures to get planes to land out there in poor weather conditions. We need to step up pace with sensor technology and database technology. Pilots are flying different approaches at a record rate and we need to help them.

<u>Mike Frank, United Airlines:</u> Where would I put my money? I'd address low visibility approach phase to give the pilot guidance in that environment. I would also put my money into wake vortices detection, microburst detection, wind shear detection, and clear air turbulence detection.

<u>Jim Daum, Boeing</u>: In order to supplement a detailed database with sensor data what are the computing requirements, update rates, and cost associated with observing with integrating and displaying the diffused data?

<u>Richard Burne:</u> I cannot directly answer the question but I can give you an estimate. I believe we are looking at the combination of the radar with the terrain database. It requires, for one image, 6,000 cpu cycles or flops processes to be done. This is a rough estimate that is done in a laboratory environment and not on the aircraft.

<u>Russ Parrish</u>: Is image fusion near an operational readiness level yet? If not, when? Sensor images contain artifacts that fusion must remove before display to pilot.

<u>Peter Smoysek</u>: Main issue is to review the main requirements for the task if you want to find out how to detect features in the landing area. It depends if you have a fused radar image with a FLIR image or FLIR image with a visible camera image. The main issue is to determine the requirements for the task and if you want to detect features in the landing area. Some sensors like some visible camera sensors are more mature than radar because there are less artifacts with the optical transformation.

<u>Ron Bolton</u>: If you were going to stick you neck out what would you say about operational readiness?

<u>Panel</u>: Concept phase right now or at full-scale.

<u>Russ Parrish</u>: We have heard during this workshop about the Boeing ESAS program. Peter presented the Honeywell fusion product, and we have heard about the Ames fusion work. The ESAS output as I understand it is that they did not show an image from a sensor to the pilot. They drew the runway outline on the HUD. They never presented a raster sensor image. The Honeywell product, as I understood Peter's explanation, took multiple sensors and fused it but never showed the image to the pilot. They extracted information and then drew something on the HUD. Ames fusion effort was to base most of the fusion information on the visible spectrum image so that you would remove the artifacts from things like the millimeter wave reflection that we saw in one of the slides. We have know about image fusion work that has been going on for years but when is it going to be ready? I want to be able to show the pilot something that does not have an artifact in it if I am going to use a sensor image. A database does not have artifacts in it

and it may be missing things and may not be in the right place and we know how to work at that. I just want to know where we are with algorithms. I am concerned with real-time but are the algorithms there to remove artifacts from these imaging sensors and give the pilot something that he does not have to be trained to recognize.

Peter Smoysek: For that specific area, they are not . More research needs to be done.

Richard Burne: Although it is a database and a radar image - it is two images that I understand that the pilot sees right now in Alaska airlines. As he is flying down he takes the image from both and does the integration in his mind. I believe before the end of the year, we will attempt to show that we can do that automatically. The image from the radar that the pilot is looking at, along with the terrain data map. That is not addressing two sensor images, unless you believe that the data map is a sensor image.

Russ Parrish: Maybe, Merit pointed out that the database comes from a sensor.

Tom Campbell: A lot of work will be done in the near future in regard to sensor fusion as well in some of the flight test that will be planned.

Jack Barry, Airforce Research Lab: Do we need to include the take-off and departure phase?

Mike Frank: Safety consideration - A restriction that we do have is that in a departure phase TERPs criteria is based on flying heading to avoid obstacles and it is pretty large - pretty gross phase. If we had better terrain data and more precise navigation, then we could operate at lower minimums then we do now. We need to include the whole airport.

Kirk Lehneis, 88th Weather Squadron, Air Force Research Lab: Please discuss the type of weather information and concept of operations for how you need to integrate weather and weather advisory information into a synthetic vision display - possibly information including updated turbulence, icing, windshear, lightening, thunderstorms, and electric static discharge potential regions. The issue is observed and forecast databases do not fully exist to support these parameters. These databases will need to be developed by NOAA and DOD in correct format to uplink to aircraft. Can anyone comment on the type of weather information and the concept of operations that need to be included?

Merit Shoucri: Just a comment I don't have the answer. Sensors play a major role both in the synthetic/enhanced vision sense and in the weather thrusts (AWIN). As soon as these two thrusts get synchronized (as you have alluded to) and be integrated into the synthetic vision on how to put in the weather effect.

Phil Brooks: We might be in a win-win situation. Everyone has a stake in this personally and in a policy sense.

Frank Muller-Nalbach: Airlines don't develop technology. This technology has the possibility of increasing operation from gate to gate. It is important that it [the technology] is developed and put on the market. Then the Airlines can choose to buy it or not

Milt Holt, NASA: We have heard several obstacles for integrating of sensors with databases, artifacts, and sensor images. A comment about the situation in Bosnia where the sensor did not work because it did not have the range that was necessary. One obstacle is the cost of these sensors. Do we know the requirements are for detecting an obstacle that would be hazard for an aircraft? Can these sensors either see the obstacles in that range or can they be made to see those obstacles at that range? Another question is cost. Do any of these sensors have technologies or design criteria that keep them from being cost effective if in fact there was enough customer database out there to utilize these sensors?

Richard Burne: Some of the obstacles we are looking at are radio towers. We do have some specifics on them as to what criteria for detection and using a radar system. We are addressing these issues currently to add those obstacles to the terrain database to detect them. If we cannot put them in the terrain database, we still have means to detect them. We are designing those requirements. As far as a cost-effective sensor - I think our approach is to use the existing sensor (weather radar) that is there in most regional transport aircraft. Pull out more information from that radar to use in multiple modes so there won't be much more cost in adding the sensor to the platform. The cost is really in the algorithms of the software and is not an expensive item. There is certification issues but we will be addressing those as well.

Ron Bolton: Comment on Databases. One of the SAE groups is saying that Part 91 operators need data for engine-out type operations and instructions to their pilots. They spend immense amounts of money every time things are changed around airports or some new obstacles are added to make sure they meet these requirements. One of the benefits of having a good database around an airport (and not just on the approach part but the departure and other areas) would be a fallout to help people on their engine-out and other procedures on takeoff. If you look at a departure chart, you wonder why pilots feel so confident as they round the corners. They don't have any data and it would be nice if they had some data to look at.

Synthetic Vision

Workshop 2

Welcome!

January 27 - 29, 1998

Carrie K. Walker
Manager, Error-Proof Flight Deck & Aircraft Systems Program
Civil Transportation Office
Airframe Systems Program Office

ASTT
irframe Systems Program

Workshop 1
December 11, 1997

Objectives:

- Introduce the Synthetic Vision Element
- Receive Initial Feedback
- Encourage Involvement
- Discuss the Procurement Process
- Establish Panel Sessions for Workshop 2

Product:

- Outline of Workshop 2 Panel Sessions

ASTT
irframe Systems Program

Workshop 2
Panel Topics

- Presentation Methods for 3-D Perspective Displays
- What's Next After Predictive CFIT 2-D Displays
- Just Do It - Can We or Can't We?
- Databases
- Advanced Vision and Sensor Technology Role

ASTT
irframe Systems Program

Workshop 2
January 27 - 29, 1998

Objective:

- Further Definition of the Synthetic Vision Element

Format:

- Panel Discussions
- Presentations

Products:

- Framework of NRA
- Multi-organizational Teams

ASTT
irframe Systems Program

Synthetic Vision Workshop 2: Next Steps

You:

- Start Scheming
- Start Teaming
- Ask Questions
- Watch the Web Site

http://www.hq.nasa.gov/office/aero/oastthp/programs/avsaf/avsafpro.htm

NASA:

- Draft NRA
- Submit Draft for Feedback
- Assemble Proposal Evaluation Team
- Finalize NRA

OASTT
irframe Systems Program

Synthetic Vision Workshop 2: Next Steps

Schedule:

- Draft NRA: Mid Summer
- Final NRA: Late Summer
- Awards: January 1999

Questions:

- Technical: Parrish & Foernsler
- Programmatic: Walker
- Specific Business/Partnering/alliance: Durham

OASTT
irframe Systems Program

51-OVER

Aviation Safety Synthetic Vision Information Contacts

Aviation Safety Program Web Site:

http://www.hq.nasa.gov/office/aero/oastthp/programs/avsaf/avsafpro.htm

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OASTT

irframe Systems Program

SINGLE SCAN

51-03

Aviation Safety Program
Synthetic Vision Element

Workshop Two
January 27-29, 1998

Lynda J. Foernsler
NASA Langley Research Center

Workshop Purpose

Provide a forum for interested parties:

- to discuss what areas they think should be included within the Synthetic Vision (SV) element to reduce the fatal aircraft accident rate.
- to give individual presentations on state of the art technologies within their organization.

Largest contributor to aircraft accident fatality rate is Controlled Flight Into Terrain (CFIT) accidents.

Approximately 30% of transport accidents are attributed to CFIT accidents.
(ref: 1995 Boeing report "Statistical Summary of Commercial Jet Aircraft Accidents - Worldwide Operations 1959 - 1995")

Even greater percentage of general aviation (GA) accidents are attributed to CFIT accidents.

Since 1958, 8300 people have died due to CFIT accidents aboard transport aircraft.

Introduction of GPWS in the 70's significantly reduced the number of CFIT accidents aboard transport aircraft.

More still needs to be done!!

Worldwide Airline Fatalities (1991-1995)

Over this 5-year period, 3028 fatalities in 59 aircraft accidents.

32% (971) of these fatalities were classified as CFIT accidents.

29% (17) of these accidents were CFIT accidents.

Data obtained from 1995 Boeing report
"Statistical Summary of Commercial Jet Aircraft Accidents - Worldwide Operation 1959-1995"

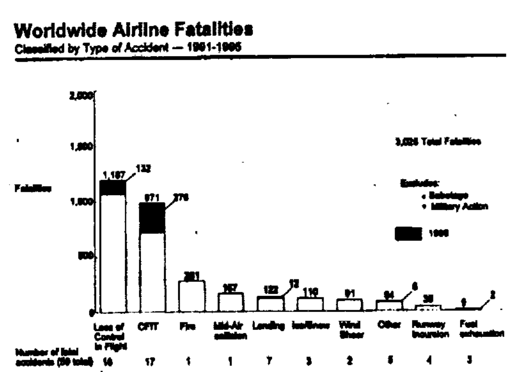


Chart obtained from 1995 Boeing report
"Statistical Summary of Commercial Jet Aircraft Accidents - Worldwide Operations 1959-1995"

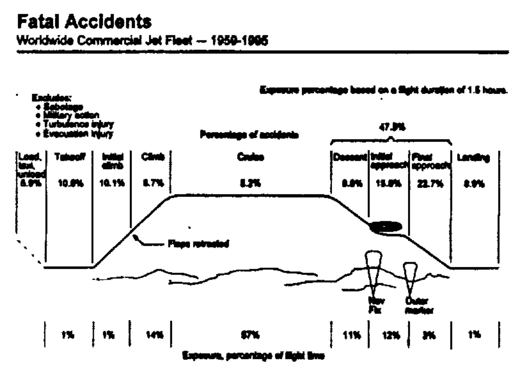
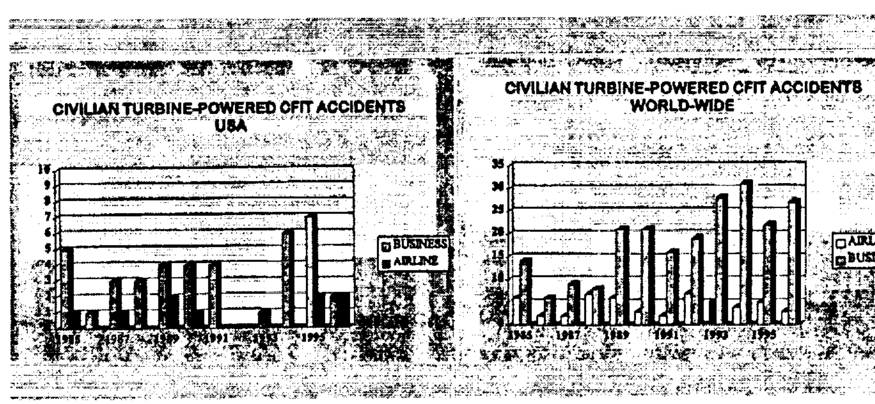


Chart obtained from 1995 Boeing report
"Statistical Summary of Commercial Jet Aircraft Accidents - Worldwide Operations 1959-1995"

Civilian Turbine-Powered CFIT Accidents



Charts obtained from Allied Signal presentation by Howard Glover, Oct. 97.

AOPA Air Safety Foundation - 1996 Nall Report

The primary cause of fatal accidents in general aviation (GA) aircraft was due to weather.

In fact, 69 percent (74 accidents) of all weather-related accidents involved fatalities.

Weather-related accidents usually involved controlled flight into terrain or other objects or uncontrolled flight because of spatial disorientation.

Current CFIT Prevention Methods

Installation of Ground Proximity Warning System (GPWS) aboard aircraft.

FSF had a 1992 goal of reducing CFIT accident rates by 50 percent by 1997.

- **Improved pilot awareness and situational awareness through:**
  - **Pilot and Controller CFIT training.**
  - **CFIT checklist for pilots - tool for evaluating CFIT risk.**

Installation of Enhanced GPWS with uses airplane position, airplane altitude, and worldwide terrain and runway databases to predict potential conflicts between airplane flight path and terrain.

Why are we interested in Synthetic/Enhanced Vision Display Technologies?

The majority of **CFIT accidents** (transport aircraft) and **Loss Of Control accidents** (GA aircraft) can be considered to be visibility-induced crew error, where **terrain visibility** would have been a substantial mitigating factor.

<u>Goal of SV element is to</u> :

Eliminate visibility-induced errors for all aircraft through the cost-effective use of synthetic/enhanced vision displays, worldwide terrain data bases, and GPS navigation.

<u>Objectives of SV element are to</u>:

1. Eliminate CFIT during all phases of flight for Part 121 Operations.

2. Provide affordable CFIT avoidance and Loss of Control avoidance for GA (Part 135, Part 91 ops)

3. Provide GPS precision approach/landing guidance for transports and business jets.

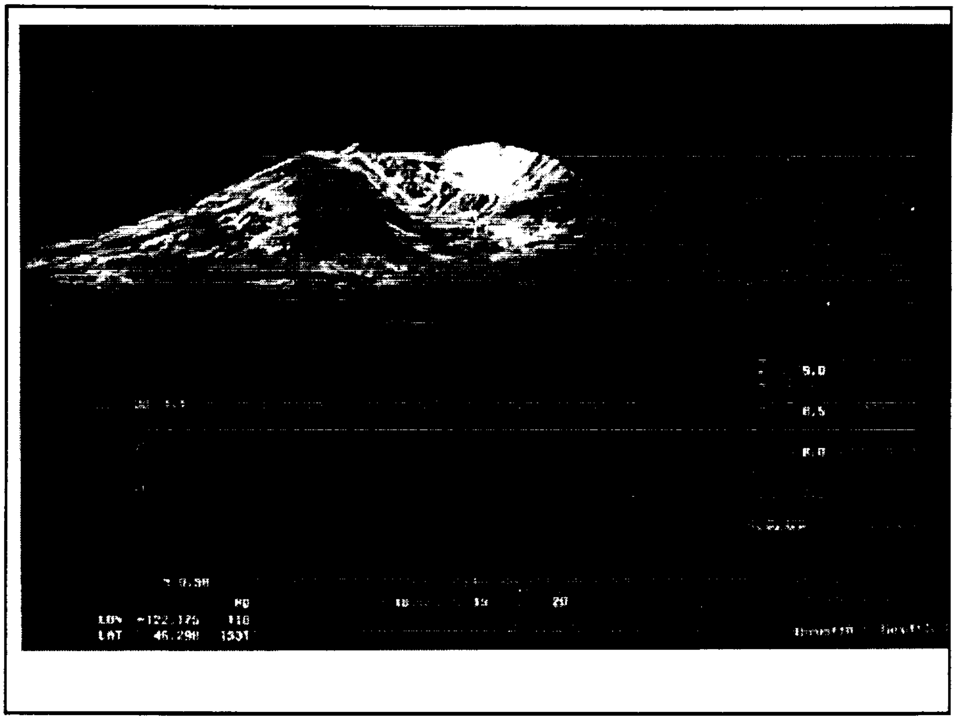
Synthetic/Enhanced Vision Display Systems

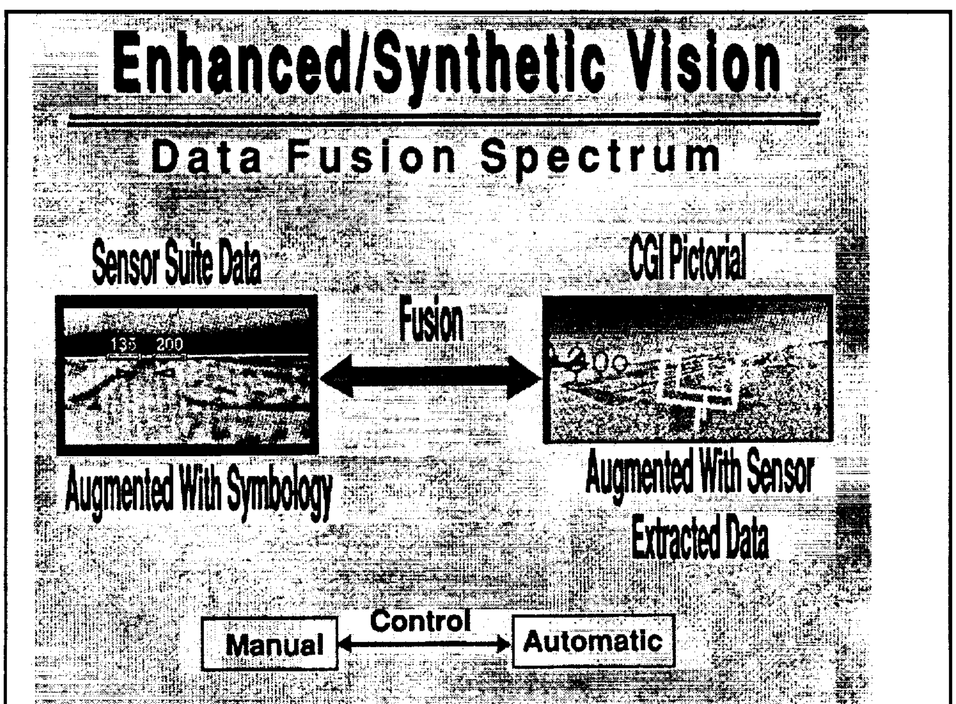
- Regardless of the outside weather conditions, these display systems allow for presentation of three-dimensional, perspective scenes with necessary and sufficient information and realism to be equivalent to bright, clear, sunny day.
- VFR-like display capability provides pilot with increased spatial awareness (e.g., terrain, attitude, and traffic).
- Symbolic information can be overlaid on these 3-d perspective scenes to enhance situational awareness and tactical guidance capability (e.g., presentation of an artificial horizon, heading, attitude indications, and pitch and/or velocity vector references).

Synthetic Vision vs. Enhanced Vision Display Concepts

Synthetic Vision systems are based on precise positioning information (GPS) within an onboard terrain database, and possibly traffic information from surveillance sources (e.g., TCAS, ADS-B, air-to-air modes of weather radar, etc.). The view of the outside world is provided by a computer-drawn image that may include information derived from a weather penetrating sensor.

Enhanced Vision systems are based on display presentations of onboard weather-penetrating sensor data combined with some synthetic vision elements. The view of the outside world is provided through a transparent display (a Heads-Up Display) of relevant flight information, which includes an image from a weather-penetrating imaging sensor.





Enhanced/Synthetic Vision
Data Fusion Spectrum
Sensor Suite Data
CGI Pictorial
Fusion
135 200
Augmented With Symbology
Augmented With Sensor Extracted Data
Control
Manual
Automatic

Synthetic Vision Element

Goal:

Eliminate visibility-induced errors for all aircraft through the cost-effective use of synthetic/enhanced vision displays, worldwide terrain data bases, and GPS navigation.

Objectives:

Low-End Thrust Provide an affordable synthetic vision display system for the low-end general aviation aircraft operating in Visual Meteorological Conditions (VMC) to transit back to VMC in the event of the unplanned, inadvertent encounter of Instrument Meteorological Conditions, including low ceiling and low visibility weather conditions. SV display system provides pilot with attitude and terrain awareness.

High-End Thrust Realize/demonstrate the potential safety benefits (elimination of CFIT accidents, GPS precision approach/landing guidance) of synthetic/enhanced vision display systems for both high-end general aviation aircraft (business jet) and commercial transports. SV display system enhances a pilot's situational awareness and tactical flight path management in low visibility weather conditions.

Synthetic Vision Element

Approach:

Through system studies, piloted simulations, systems technology assessments, and integrated concept assessment flight tests:

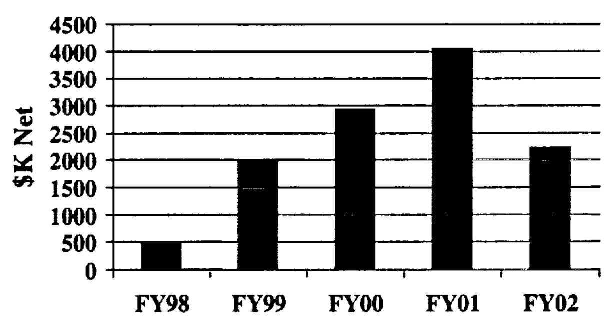
- Evaluate cockpit systems technology suitable for integration into synthetic/enhanced vision display systems
- Iteratively develop and evaluate candidate synthetic vision display concepts and systems for terrain and attitude awareness in low-end general aviation aircraft
- Iteratively develop and evaluate candidate synthetic/enhanced vision display concepts and systems for situational awareness (e.g., terrain, traffic, and attitude) in high-end general aviation and commercial transport aircraft

Synthetic Vision

Approach: (cont.)

- **Metrics and Exit/Success Criteria**
  - Simulation Evaluations / Comparisons
  - Flight Tests
  - Commercial Package Development
- **Anticipated Partner Participation**
  - Low-End Thrust
    - AGATE Consortium
    - GA Avionics & Manufacturers Industry
    - FAA
    - Universities
  - High-End Thrust
    - User Community (ALPA, APA)
    - Avionics & Manufacturers Industry
    - FAA
    - Universities

SV Funding Profile



	FY 98	FY 99	FY 00	FY 01	FY 02
$K Net	500	2000	2925	4050	2230

Outline

- Partnering Philosophy
- Benefits of Collaborative R&D
- What is a NRA?
- Desired Proposal Attributes

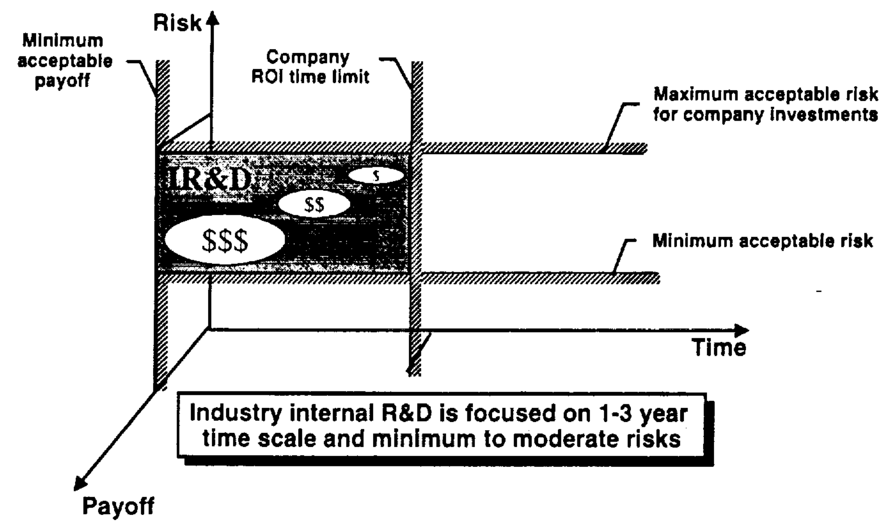
ASTT

Partnering Philosophy

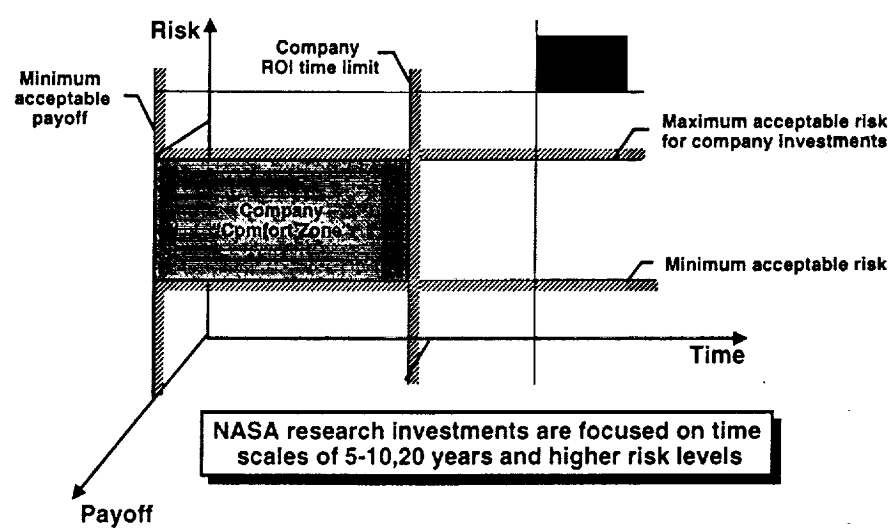
- NASA funding to serve as catalyst
  - Attack hurdles to development/certification/implementation
- NASA will not pay for <u>all</u> of <u>anything</u>
  - Leverage resources, cost sharing
- Stretch industry investment time scales
  - Near-term focused strategies limit ROI in changing NAS (avoid Band-Aids, search for cures)
  - Gov't role in near-term less clear
- Increase risk tolerance through partnerships
  - Systems implementation provide more rapid ROI
  - Reduce chance of taking wrong safety technology "fork in the road" to NAS modernization.

ASTT

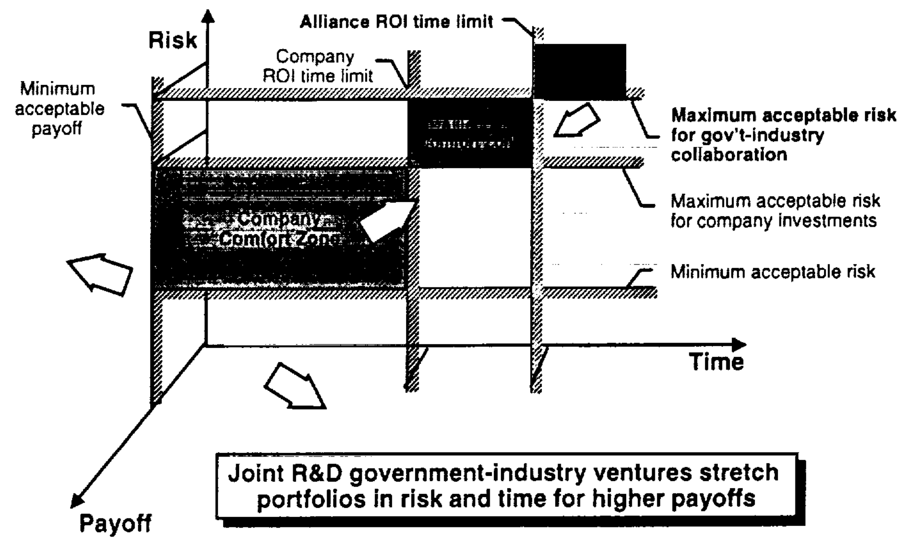
INDUSTRY PORTFOLIO OF R&D INVESTMENTS



NASA R&D INVESTMENTS



PORTFOLIO STRETCH AND BALANCE

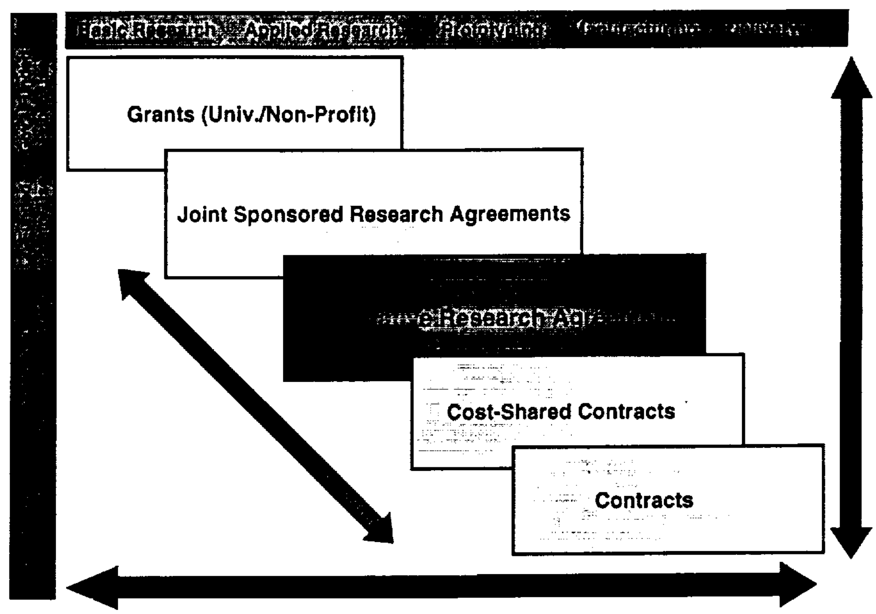


What is a NRA? Why?

- **NRA = NASA Research Announcement**
  - Requests research proposals, conceived by the offerors, in broad technical areas which are difficult to define
  - Impossible to draft specification/RFP in sufficient detail
  - Multiplicity of possible approaches
  - To encourage new and creative approaches
- **Can not use NRA to:**
  - Solicit proposals for a specific system or hardware procurement
  - In place of RFP when requirement is narrowly defined
- **Multiple awards of grants, contracts, cooperative agreements, or other agreements can result from NRA**
  - NASA will determine appropriate instrument
  - Contracts are subject to FAR
  - Grants/Coop Agreements subject to NASA Grant and Cooperative Agreement Handbook (NPG 5800.1)

ASTT

GOV'T BUSINESS TOOLS



GRANTS/COOPERATIVE AGREEMENTS VS. CONTRACTS

Grants

- To carry out public goal of support or stimulation
- Substantial involvement is NOT expected by gov't
- Gov't carries all risks

Cooperative Agreements (Vested Partnerships)

- Gov't/Industry co-leadership role
- 50/50 Cost-shared (Shared risk)
- Fixed-funding (Gov't share)
- Gov't participates substantially in effort
- "alliances" encouraged
- Intellectual property rights negotiable
- GAAP, commercial accounting standards
- Streamlined "procurement" process

ASTT

Desired Synthetic Vision Proposal Attributes

- **Proper technical breadth/focus & direction to contribute <u>10x</u> goal**
  - Address display problems, implementation hurdles, system integration
  - Technically aggressive (no nibbling at the edges)
  - Goal-oriented, data-driven, metrics-monitored
- **Partnerships representing aviation community**
  - Coordinates issues from manufacturers, operators, regulators, users, etc.
  - Leverages activities of other gov't agencies, alliances, and programs
  - Operationally realistic & implementable
- **Considers complete path from technology development to test to certification to implementation**
  - Funded research may only address one phase but all relevant issues included in research plans
  - Identifies transition path (retrofitable, interoperable, upgradeable, NAS modernization)
- **Efficiently managed team through one agreement**
  - Joint partnerships/alliances wherever possible
  - One business partner (prime or alliance arrangement)

ASTT

S2-06

Advanced Navigation Instruments

Presented by Dr. Eric Theunissen

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handouts

Advanced Navigation Instruments

Dr. Eric Theunissen
Faculty of Information Technology and Systems
Delft University of Technology

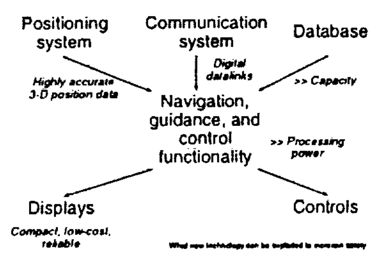
URANIUM United Research into Advanced Navigation InstrUMents

Overview

- The potential to increase safety
- The URANIUM network
- DELPHINS I (1990-1996) research
- DELPHINS II (1996-2000) research
- DELPHINS display system
- Conclusions
- Video

URANIUM United Research into Advanced Navigation InstrUMents

The potential to increase safety



URANIUM United Research into Advanced Navigation InstrUMents

The URANIUM network

- Current members:
  - Delft University of Technology
    - Faculty of Information Technology and Systems
  - Munich University of Technology
    - Institute of Flight Mechanics and Flight Control
  - Ohio University
    - Avionics Engineering Center

URANIUM United Research into Advanced Navigation InstrUMents

The URANIUM network

Accurate 3-D position determination (D)GPS, integrated positioning	OU & TUD
Digital datalinks C-band, VHF	OU & TUD
High performance computer graphics Guidance symbology, terrain depiction, traffic depiction	TUM & TUD

URANIUM United Research into Advanced Navigation InstrUMents

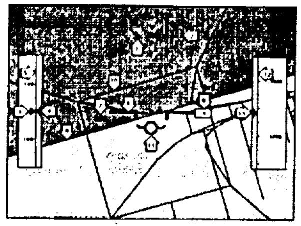
DELPHINS I (1990-1996)

- To identify, structure, and place into context the technical, control-theoretical, perceptual, and cognitive aspects involved in the design process of an MMI for 4-D navigation based on the presentation of spatially integrated data

URANIUM United Research into Advanced Navigation InstrUMents

DELPHINS I, 1992

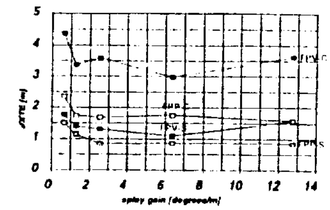
- Study into the representational aspects



URANIUM United Research into Advanced Navigation InstrUMents

DELPHINS I, 1993

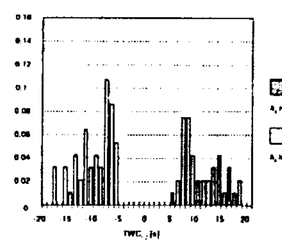
- Study into the effects of error-gain and prediction



URANIUM United Research into Advanced Navigation InstrUMents

DELPHINS I, 1994

- Study into error-neglecting control
- In-flight testing



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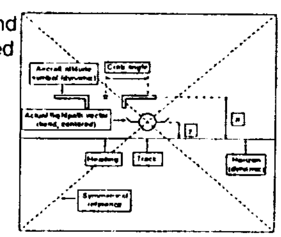
DELPHINS I, 1995

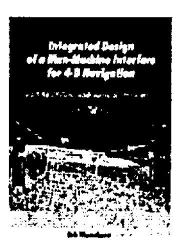
- Study into attitude and velocity vector aligned frames of reference



URANIUM United Research into Advanced Navigation InstrUMents

DELPHINS I overview

- Integrated Design of a Man-Machine Interface for 4-D Navigation



URANIUM United Research into Advanced Navigation InstrUMents

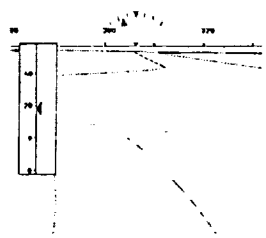
DELPHINS II (1996-2000)

- Towards the integration of perspective displays into the flightdeck
- Focus on a wider variety of applications
- Address integration issues
- Sponsored by the Dutch Technology Foundation STW

URANIUM United Research into Advanced Navigation InstrUMents

DELPHINS II (1997)

- Study into surface movement guidance display formats (frame of reference, prediction)
- Cooperation with the AEC for integration in test vehicles



URANIUM United Research into Advanced Navigation InstrUMents

DELPHINS II (1998)

- Pilot-in-the-loop study in cooperation with Munich University of Technology
- Integration and testing of taxi guidance display in AEC SMURF
- Study into influence of position data latency
- Development of data-shaper

URANIUM United Research into Advanced Navigation InstrUMents

System development

- 1990: Display hardware (PC-based)
- 1991 DELPHINS Display Design System
- 1991: Integration in moving-base flight simulator
- 1994: PC-based experimental in-flight system
- 1997: New generation display processor
- 1998: DELPHINS II in-flight target system

URANIUM United Research into Advanced Navigation InstrUMents

DELPHINS II display system

- Experimental system for research applications
- Computer aided design, autocode generation
- COTS, PC-based
- All the usual features (anti-aliasing, gouraud shading, alpha blending, texture mapping, tri-linear mipmapping, subpixel correction)
- High performance, low cost (<2K$)

URANIUM United Research into Advanced Navigation InstrUMents

Conclusions

- Today, depiction of spatially integrated data is easy
- An approach has been developed which allows many of the design decisions to be evaluated in the appropriate context
- An experimental display computer has been developed which costs less than 2K$
- An evolutionary introduction of 3-D is feasible

URANIUM United Research into Advanced Navigation InstrUMents

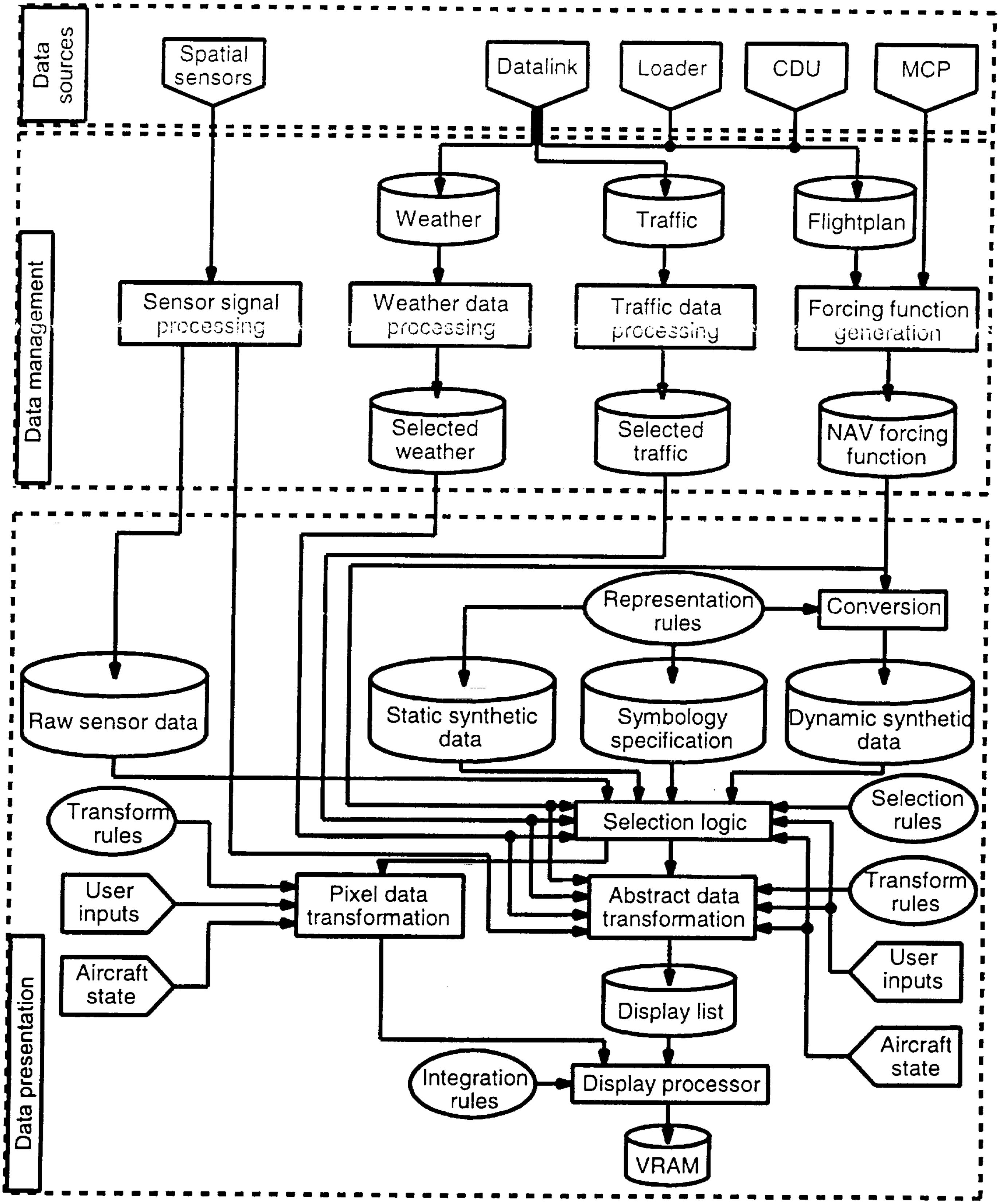


Fig. 1.2. Overview of the systems involved in the presentation of navigation data. From *'Integrated Design of a Man-Machine Interface for 4-D Navigation'*, Theunissen, E. (1997), ISBN 90-407-1406-1, Delft University Press, Delft, The Netherlands.

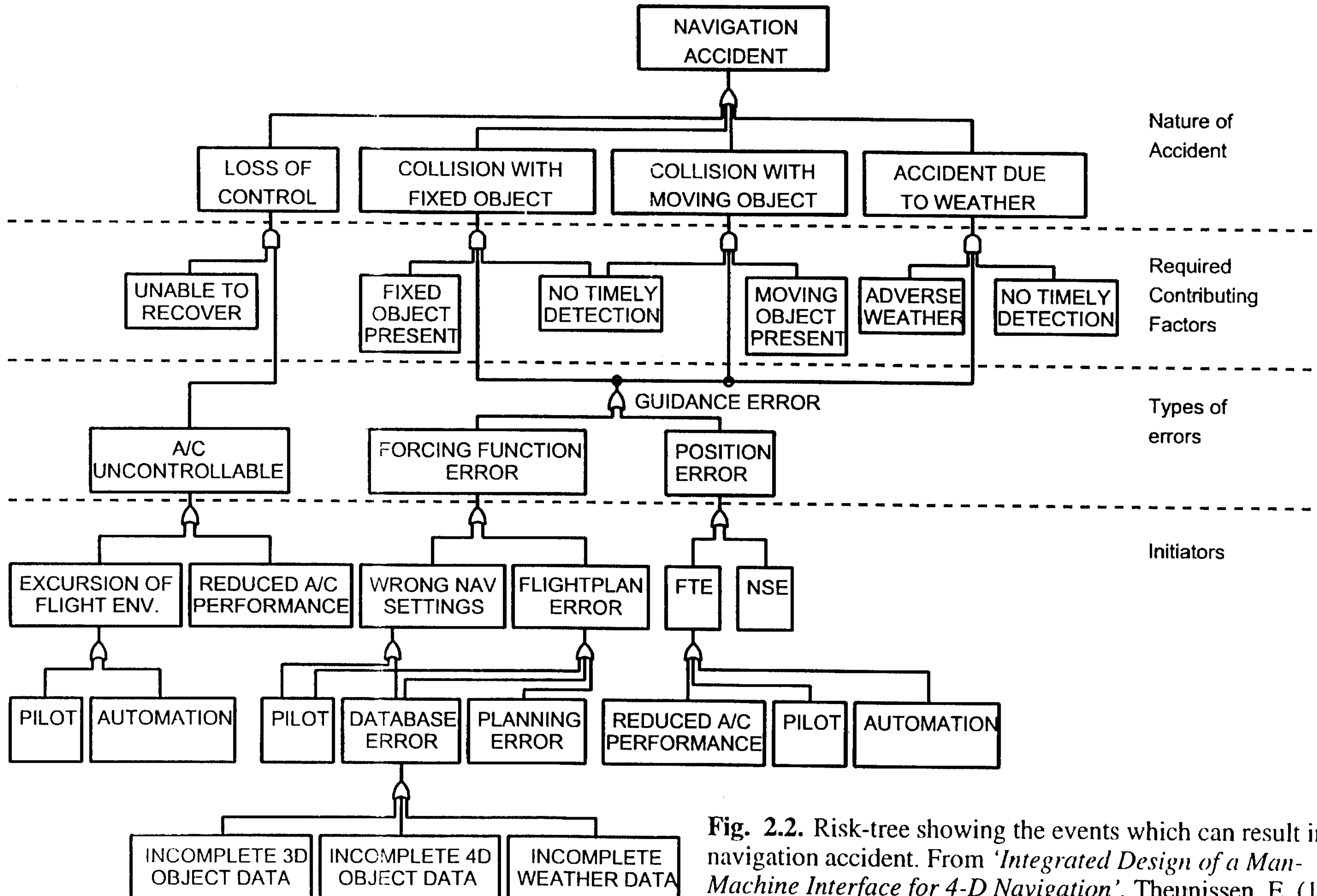


Fig. 2.2. Risk-tree showing the events which can result in a navigation accident. From *'Integrated Design of a Man-Machine Interface for 4-D Navigation'*, Theunissen, E. (1997), ISBN 90-407-1406-1, Delft University Press, Delft, The Netherlands.

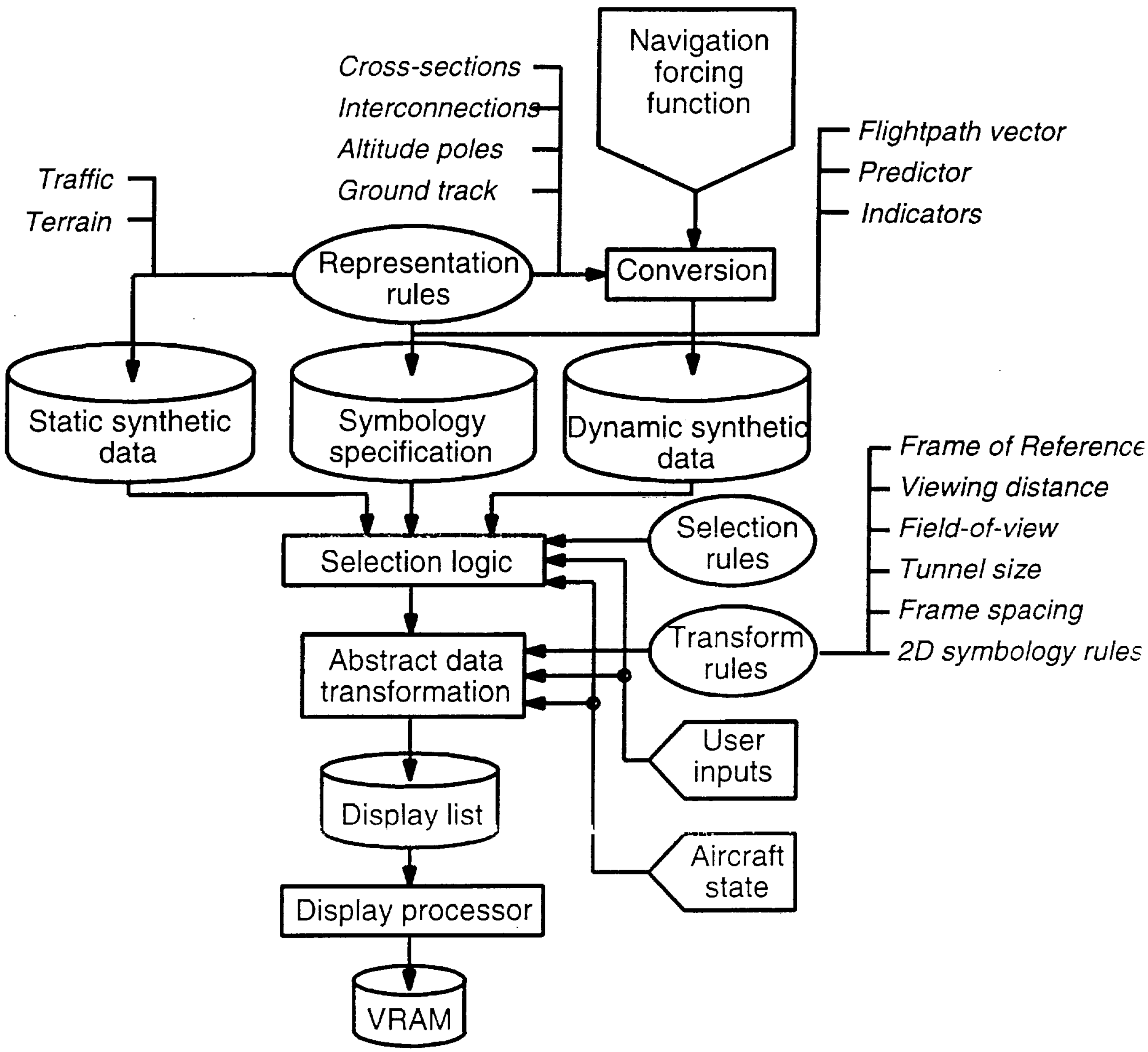


Fig. 5.1. Transformation of the forcing function into an image which is stored in video ram (VRAM). From *'Integrated Design of a Man-Machine Interface for 4-D Navigation* Theunissen, E. (1997), ISBN 90-407-1406-1, Delft University Press, Delft, The Netherlands.

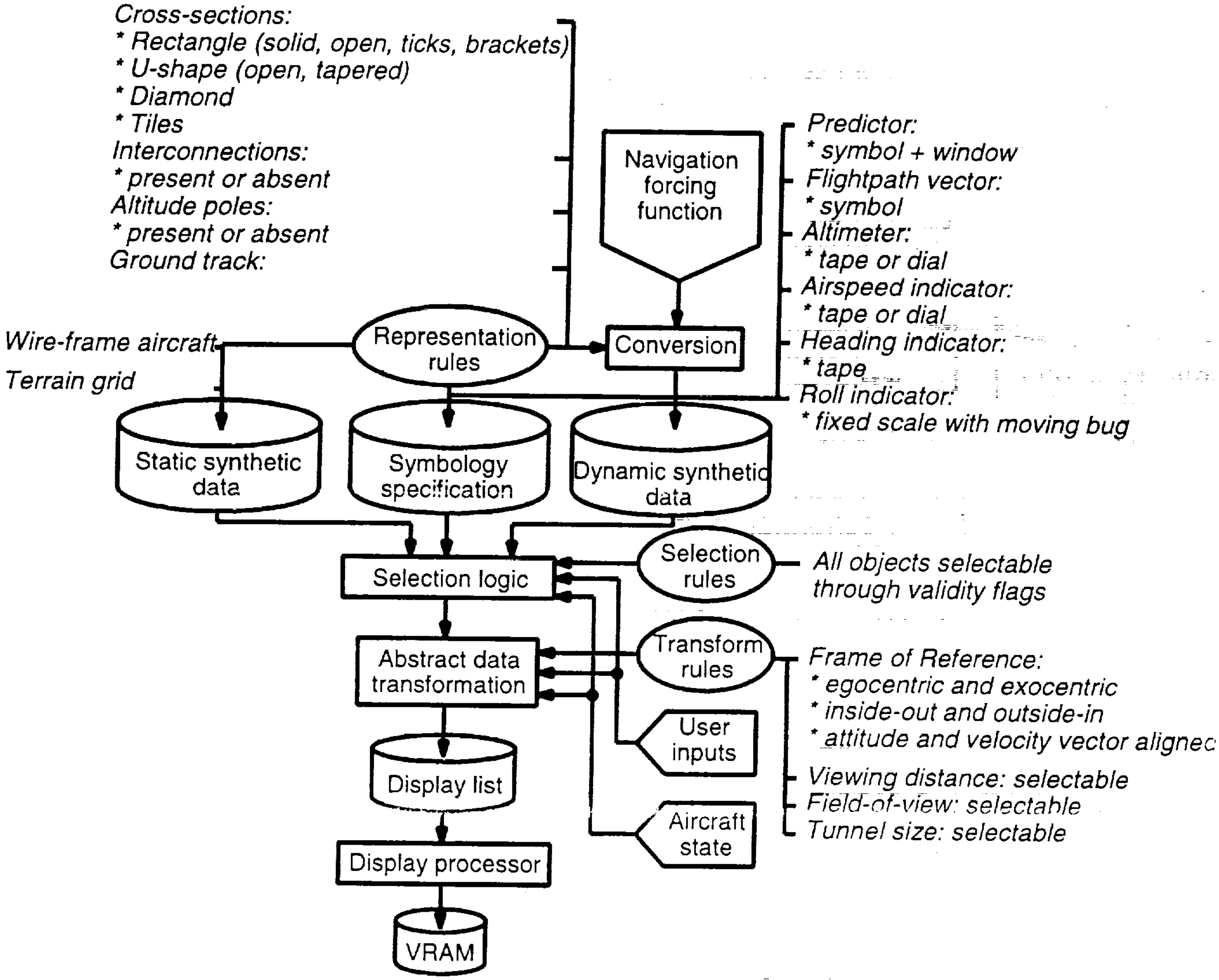


Fig. 6.26. Overview of the functionality which has been implemented. From *'Integrated Design of a Man-Machine Interface for 4-D Navigation'*, Theunissen, E. (1997), ISBN 90-407-1406-1, Delft University Press, Delft, The Netherlands.

Flight Test Experience with 3D Terrain Displays

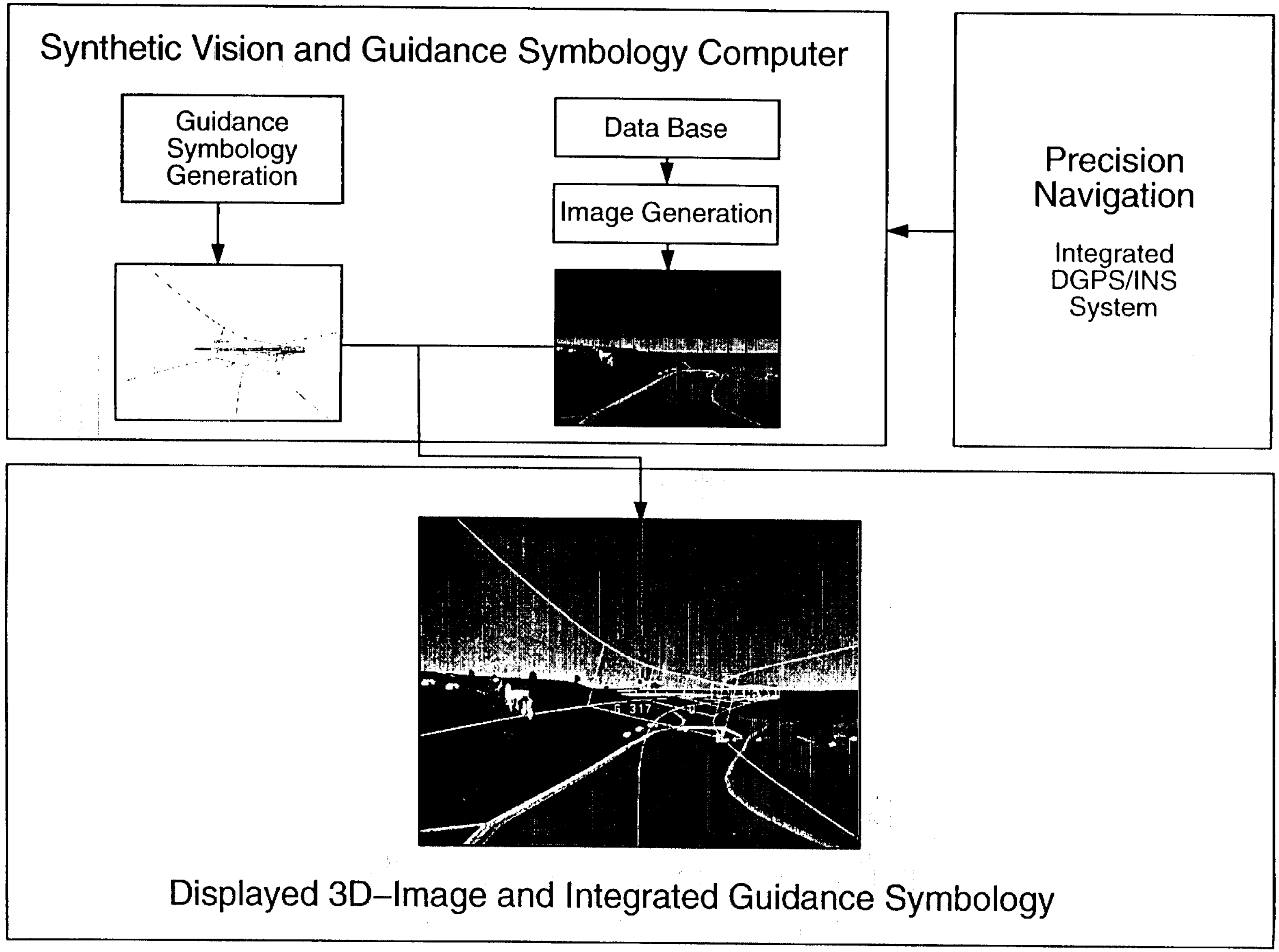
Dipl.-Ing. K. Dobler, Prof. Dr.-Ing. G. Sachs
Institute of Flight Mechanics and Flight Control
Technische Universität München

URANIUM – United Research Into Advanced Navigation InstrUMents

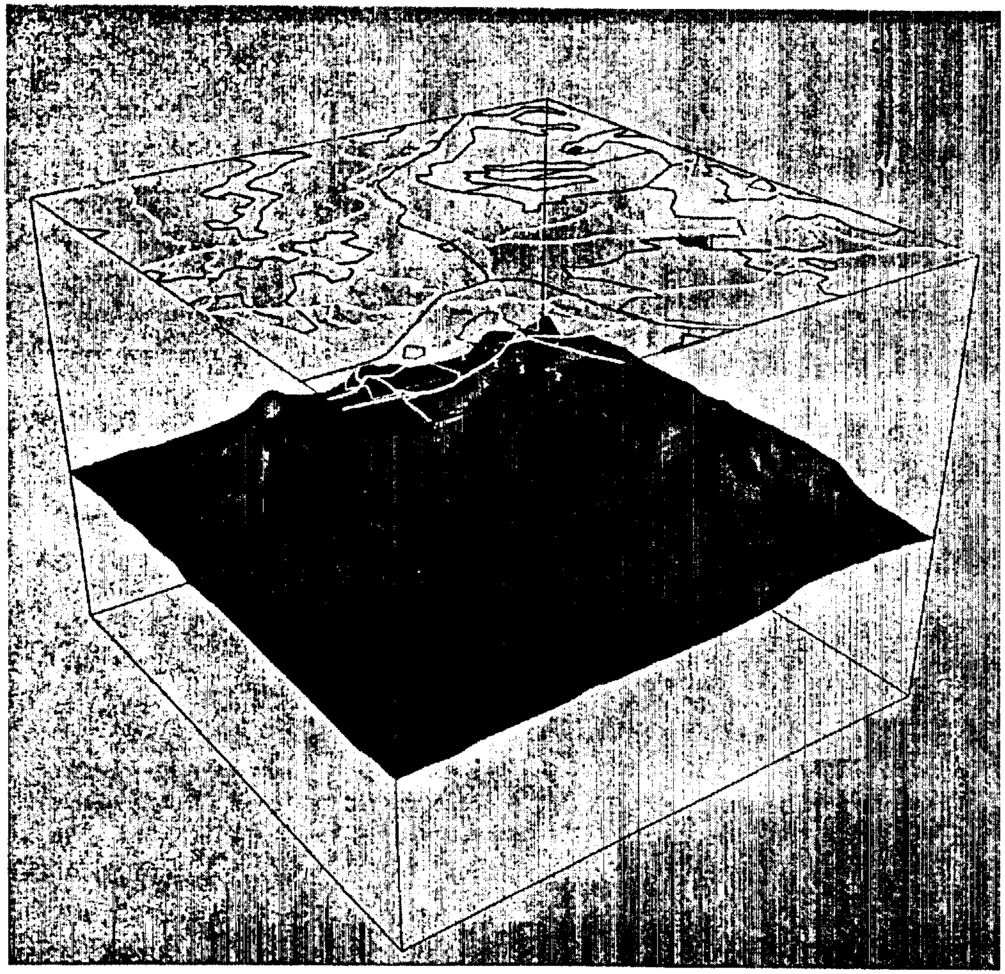
Overview

- Basic Concept
  of Computer Generated Synthetic Vision
- Adaptive Realtime Terrain Triangulation
- Flight Test Program and Equipment
- Flight Test Results (Video)

Synthetic Vision Concept

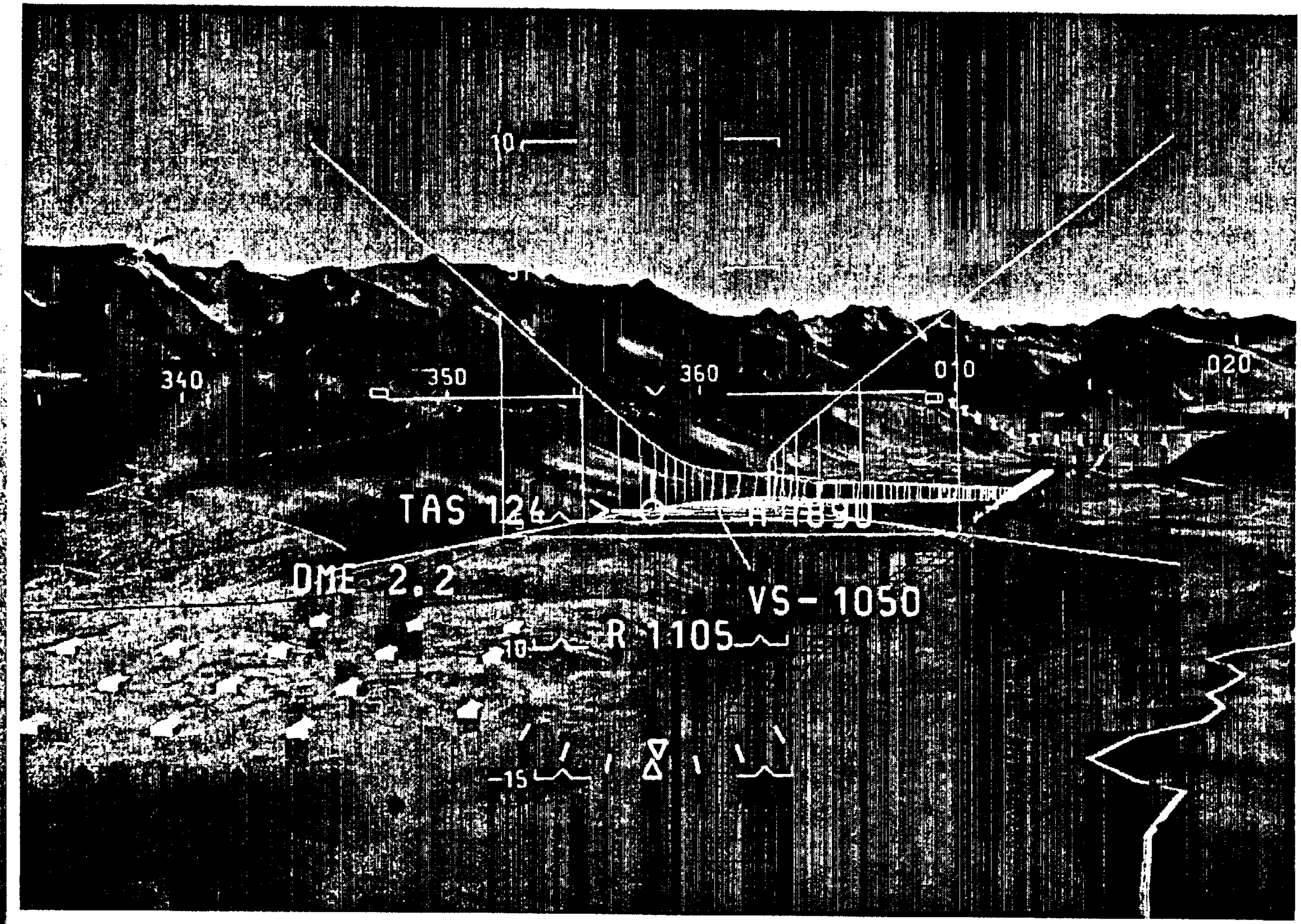


Digital Terrain Data Base



- Terrain Elevation Data
- Feature Analysis Data
- Obstacle Charts
- Satellite Images

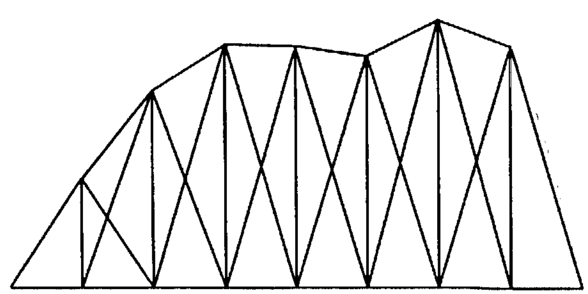
Synthetic Vision with Integrated Flight Guidance Symbology



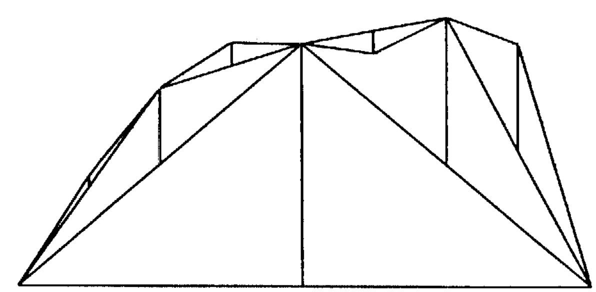
URANIUM – United Research Into Advanced Navigation InstrUMents

Adaptive Realtime Terrain Triangulation

- Hierarchical interpolation of elevation data
- Major benefits:
  - Possibility of data compression
  - Fully user controllable level of detail



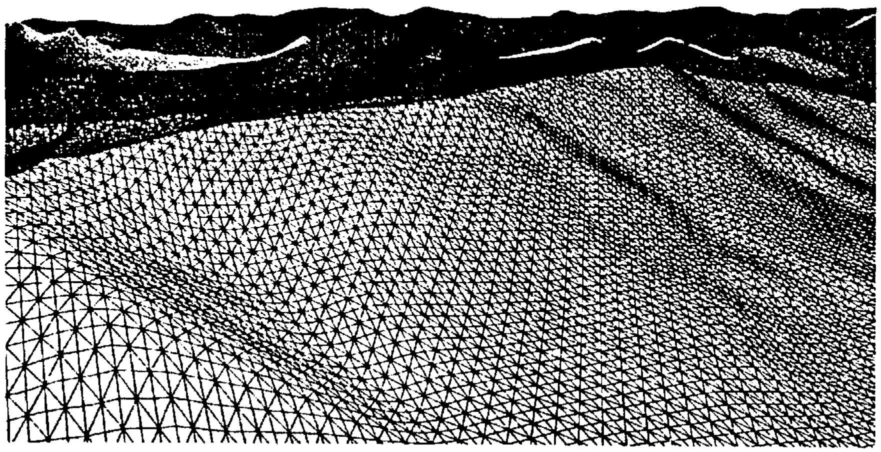
nodal basis



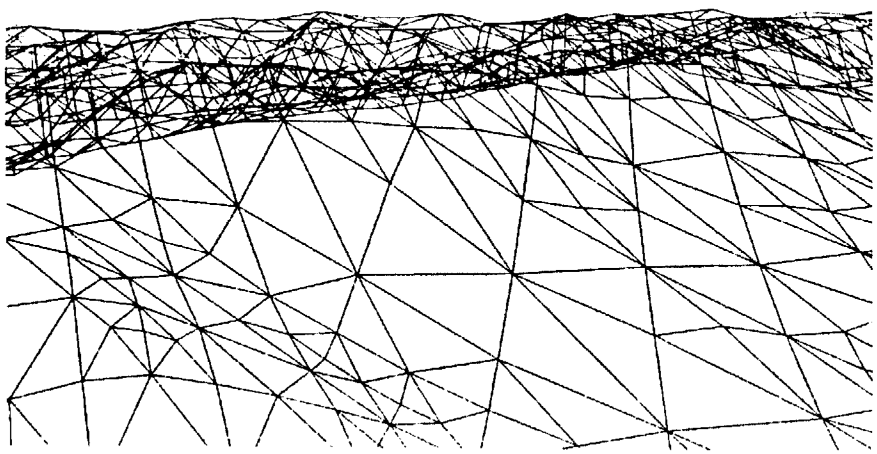
hierarchical basis

Adaptive Realtime Terrain Triangulation

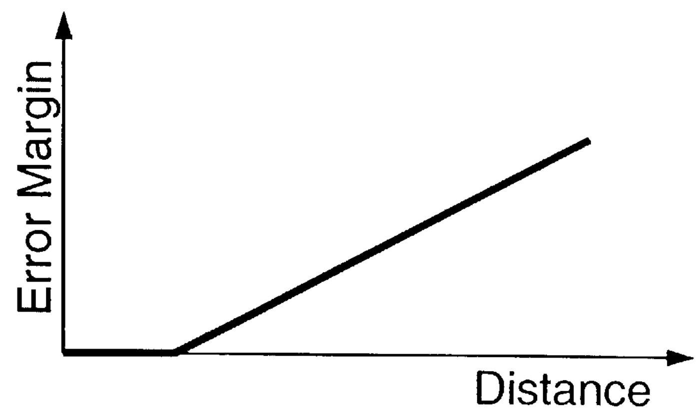
65.7 kTriangles



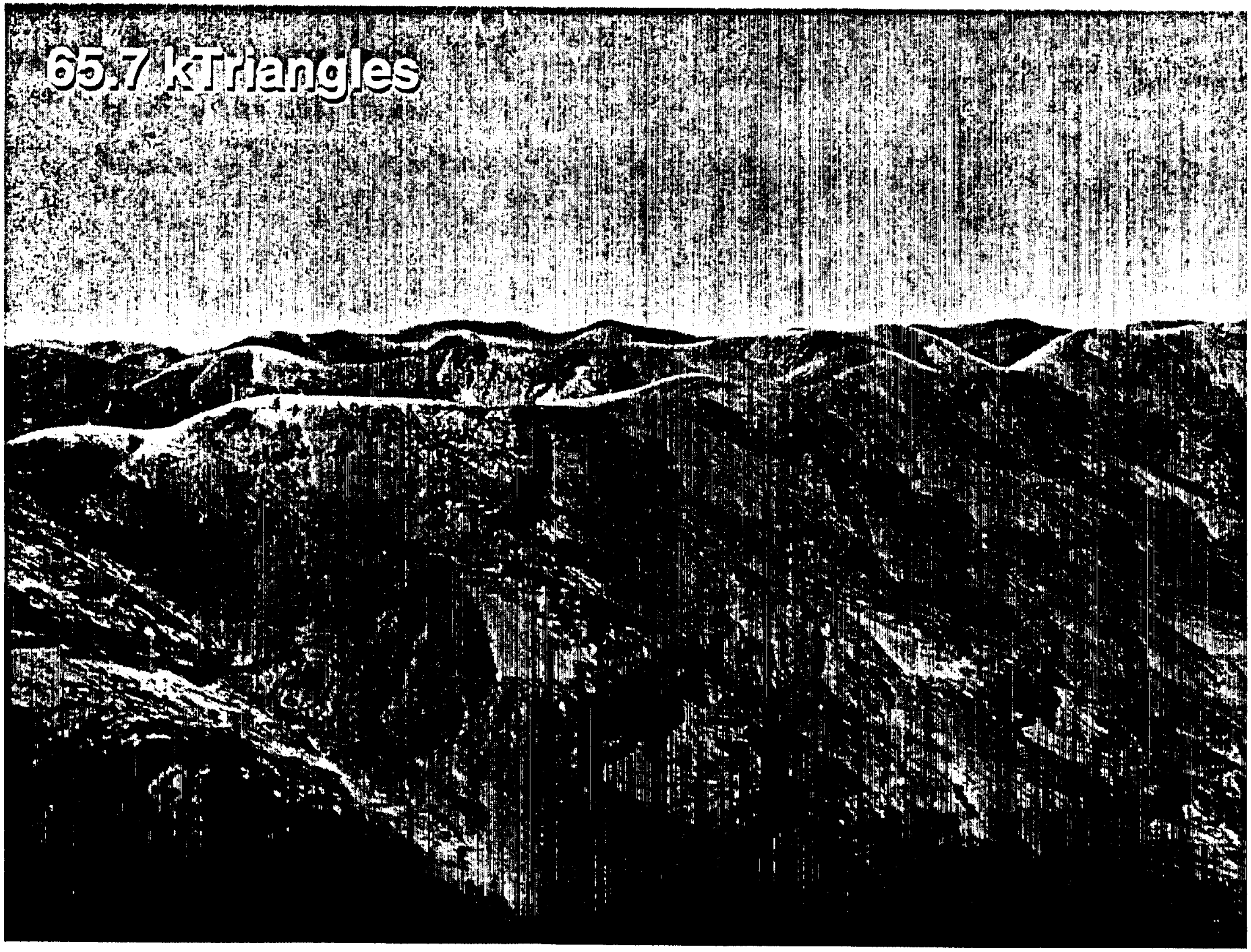
1.5 kTriangles



Level of Detail

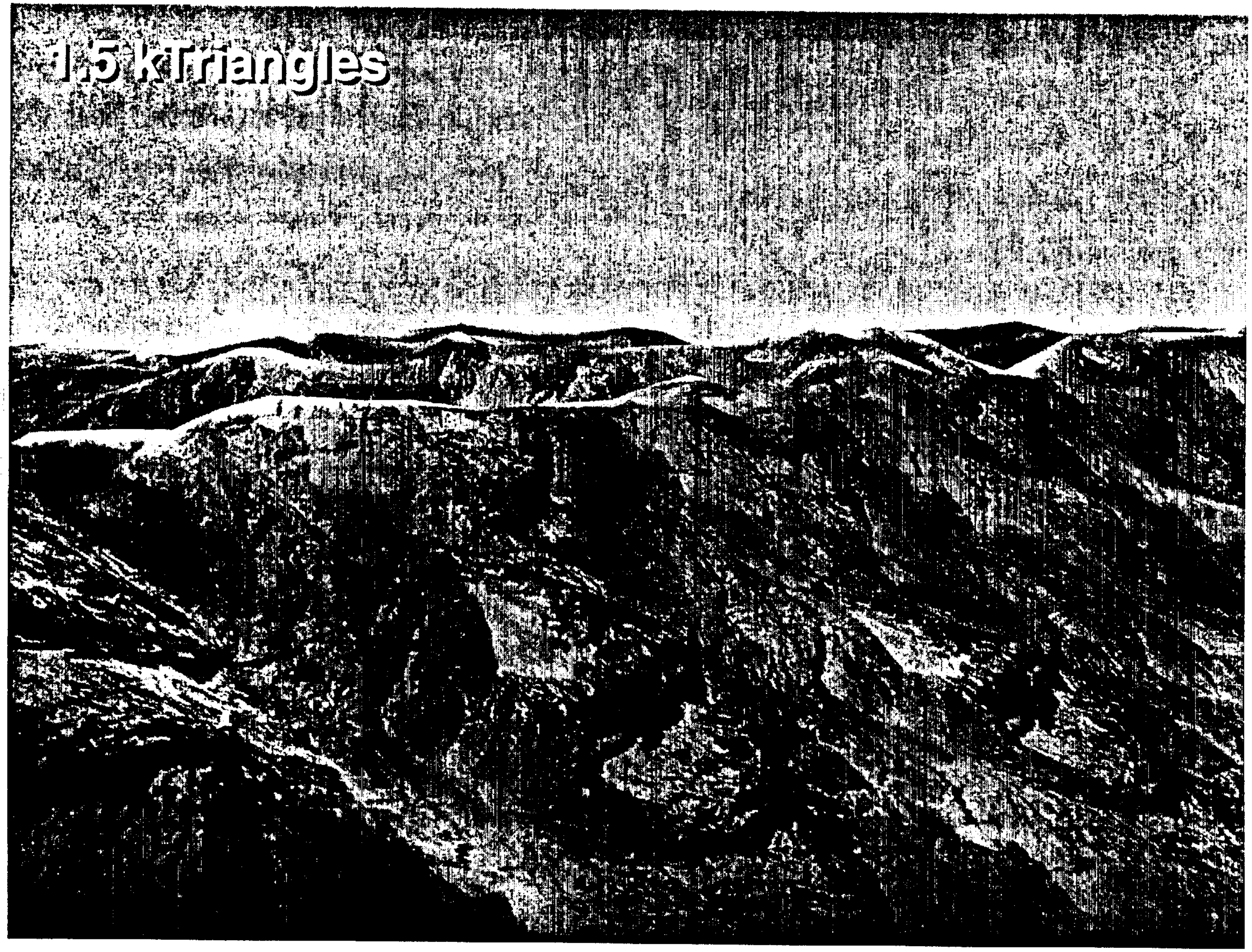


Adaptive Realtime Terrain Triangulation



URANIUM – United Research into Advanced Navigation InstrUMents

Adaptive Realtime Terrain Triangulation

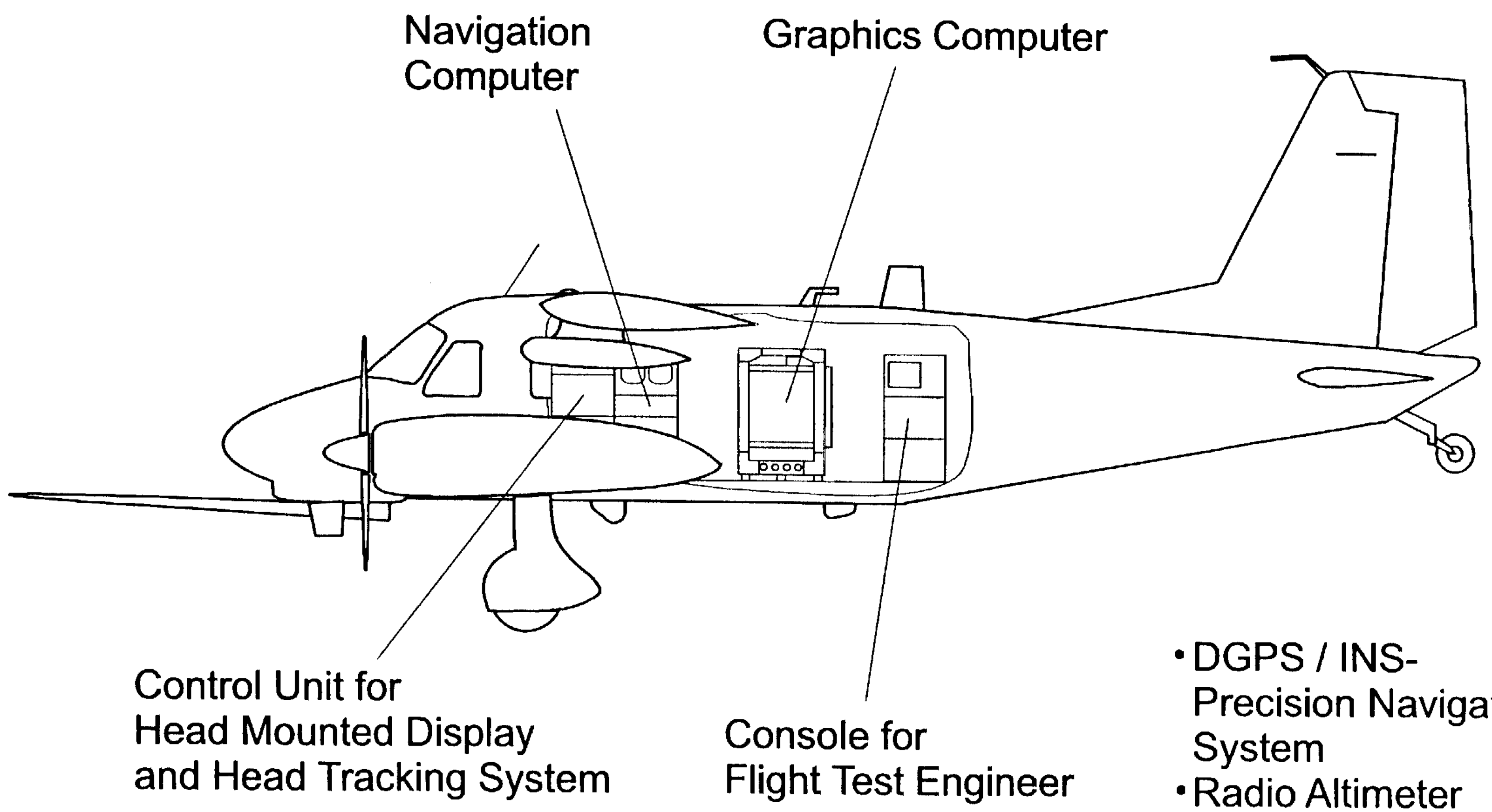


URANIUM – United Research into Advanced Navigation InstrUMents

Synthetic Vision Flight Test Program

- **Precision Approach and Landing**
  October 10–14, 1994, Braunschweig Airport, Germany
- **Low Level Flight**
  December 12–16, 1994, Altmühl River Valley, Germany
- **Curved and Steep Approach**
  July 31 – August 4, 1995, Lugano Airport, Switzerland
- **Low Level Flight – Short Approach**
  March 18–22, 1996, Schwarzwald / Offenburg Airport, Germany
- **Low Level Flight – Curved Approach**
  July 7–10, 1997, Schwarzwald / Freiburg Airport, Germany

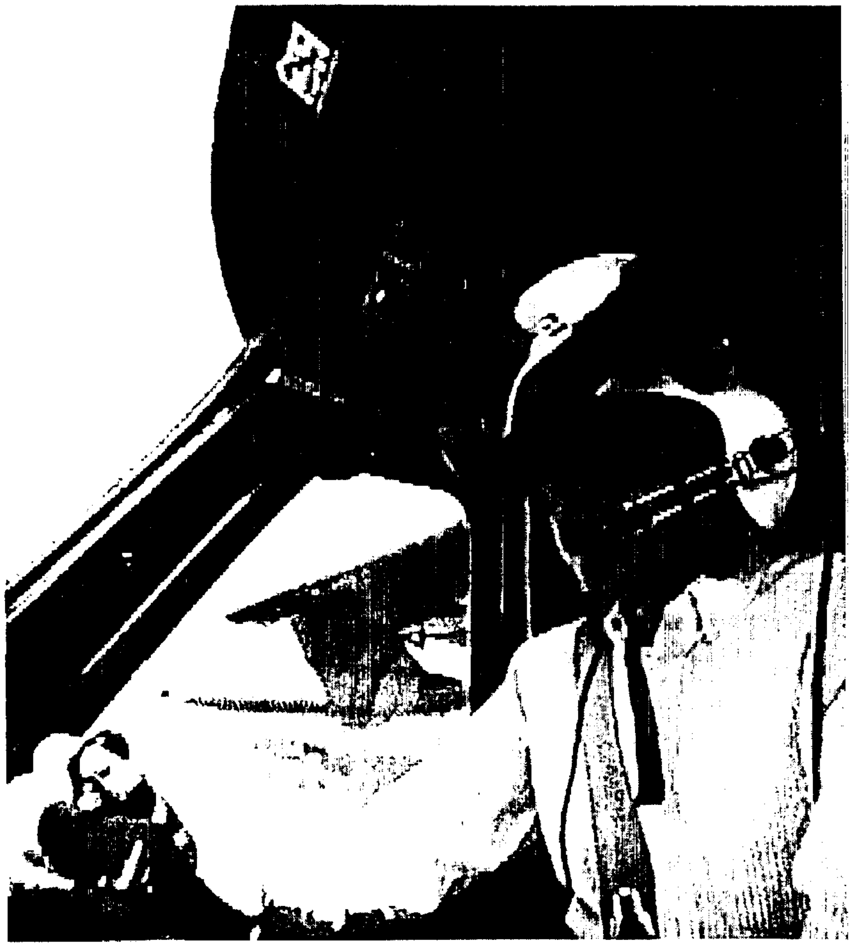
Test Vehicle – Dornier 128 D-IBUF
Technische Universität Braunschweig



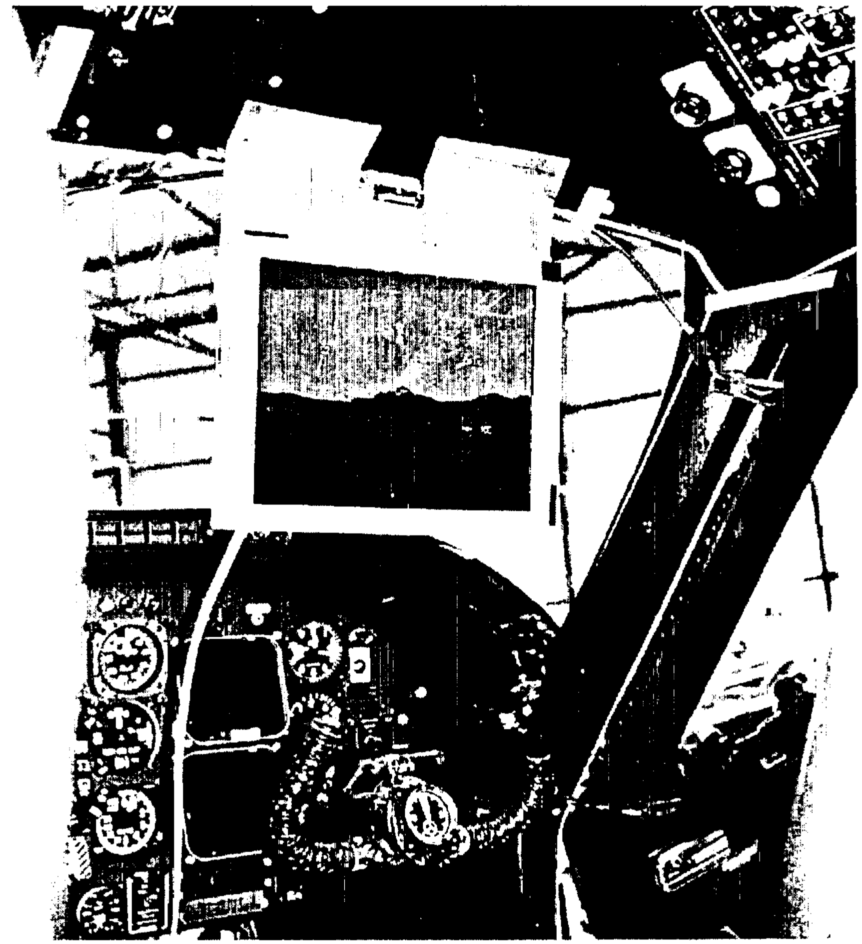
- DGPS / INS-Precision Navigation System
- Radio Altimeter

URANIUM – United Research into Advanced Navigation InstrUMents

Applied Display Options



Head Mounted Display



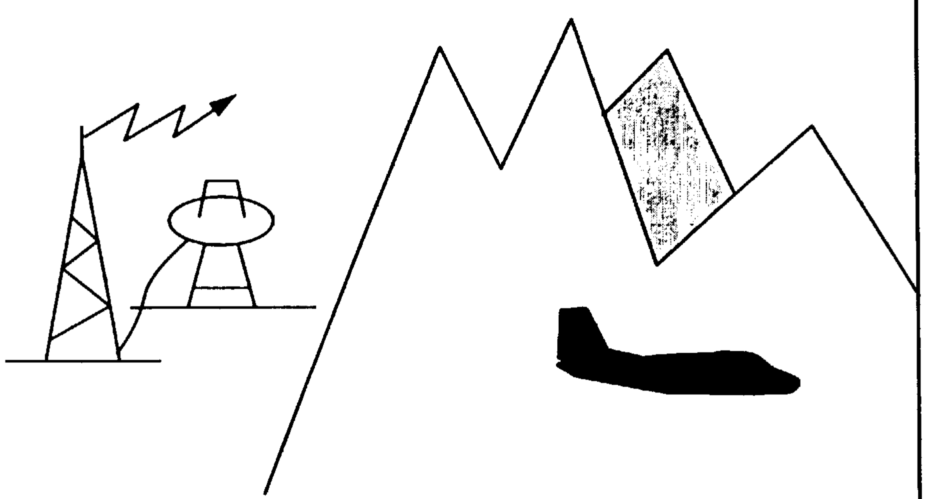
Head Down Display

Wide Area DGPS

(Altmühltal, Schwarzwald)

LF Data Link
300 bit/s

Distance ≈ 300 km
Accuracy ≈ 3 m

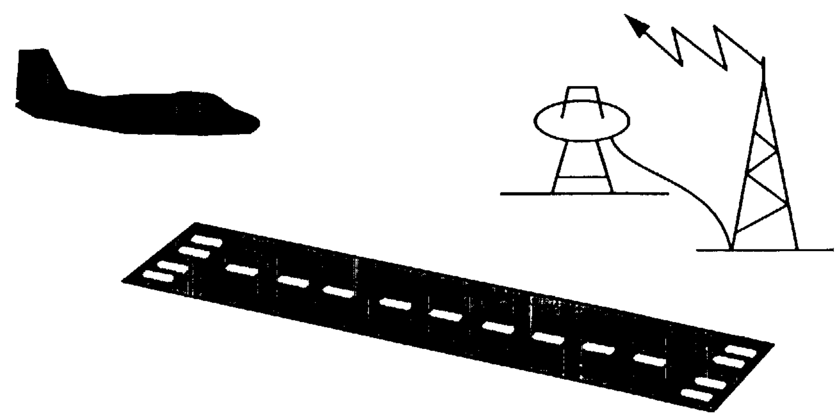


Local Area DGPS

(Braunschweig, Lugano)

UHF Data Link
4800 bit/s

Distance < 25 km
Accuracy < 0.5 m



Conclusions

- Synthetic Vision Experience at TU München
  - Successfully applied in several flight test series
  - Precise guidance capability
  - Applicable for a wide range of demanding flight tasks
- Test Facilities Available for Further Research
  - Research aircraft Dornier 128 with high precision DGPS
  - Fixed based research flight simulator

Further information: dobler@lfm.mw.tu–muenchen.de

[redacted]

S4-03

T-NASA (Taxiway Navigation and Situation Awareness) System: A Human-Centered Design Paradigm

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OVERVIEW / DESIGN PROCESS

PROBLEM & GOALS
TAP (Terminal Area Productivity) Program

TASK ANALYSIS
Current Taxi Operations

TECHNOLOGY ASSUMPTIONS
Aircraft/Airport Technology

INFORMATION REQUIREMENTS
Info. Available, Missing in Low-Vis.

SYSTEM REQUIREMENTS
Display Elements
Design/Usage Philosophy

SYSTEM DEFINITION
T-NASA (Taxiway Navigation and Situation Awareness) System
- Scene-Linked HUD Symbology
- Perspective Moving Map Display
- 3-D Audio Ground Collision and Warning

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TAP PROGRAM RATIONALE

DELAYS

23 major U.S. airports > 20,000 delay hrs/yr
40 major U.S. airports expected in Year 2000

1990 - 1993, 312,000 flights/yr delayed > 15 min
64% poor weather; 28% congestion; 8% other

COST

$3 billion for airline operations & $6 billion for passenger delays (est. 1990)
50% increase projected in costs in Year 2000

TRAFFIC GROWTH

Projected 32% increase in air traffic in next 10 yrs

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CURRENT TAXI OPERATIONS

– ANDRE (1995) JUMP SEAT STUDY

- **LOSS OF VISUAL CUES**

  "Under low-visibility conditions I taxi at 1/2 to 1/3 the speed...."

  "Delays in taxiing under low vis. are sometimes caused by ground control having to tell you every turn and where you are at."

- **DEFICIENCIES IN AIRPORT VISUAL ENVIRONMENT**

  "Some signs are burned out and therefore not visible...during poor weather."

  "Only knew where to go using the map," (noting signs covered with weeds)

- **INEFFECTIVE TOWER / COCKPIT COMMUNICATIONS**

  "[Ground Control] didn't say which way to go... we'll just go our way."

- **MID-TAXI ROUTE CHANGES**

  "Once you get a mental picture of the route...it's hard to replace it..."

- **TAXI IS HEAD-UP, EYES-OUT TASK**

  "I like [the] idea of moving map display... should be a secondary display, not a primary display, since it requires me to be heads-down."

  "[In Low-Vis.] I see things out the window (lights on...aircraft, RWY markers)."

[redacted] OVERVIEW / DESIGN PROCESS

PROBLEM & GOALS
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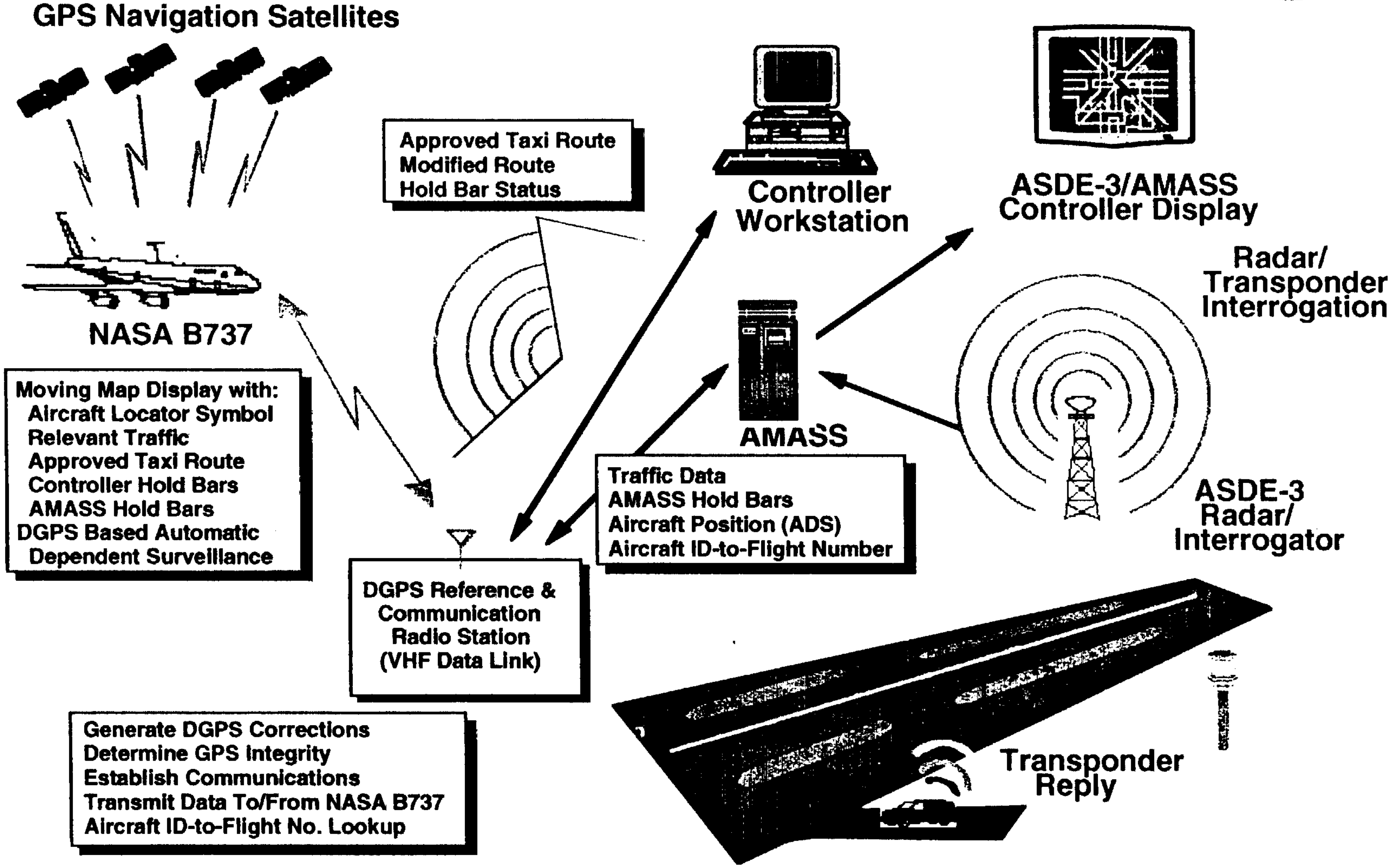
AIRPORT / AIRCRAFT TECHNOLOGY ASSUMPTIONS



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- Perspective Moving Map Display
- 3-D Audio Ground Collision and Warning

INFORMATION REQUIREMENTS FOR LOW-VISIBILITY TAXI

- MISSING INFORMATION
  - Aircraft & ground vehicle traffic
  - Global visual navigational references (terminal, runway, gate)
  - Some local visual navigational references (distant turns)

- AVAILABLE INFORMATION (DEGRADED)
  - Centerline and centerline lights
  - Taxiway edges
  - Near signage

OVERVIEW / DESIGN PROCESS

PROBLEM & GOALS
TAP (Terminal Area Productivity) Program

TASK ANALYSIS
Current Taxi Operations

TECHNOLOGY ASSUMPTIONS
Aircraft/Airport Technology

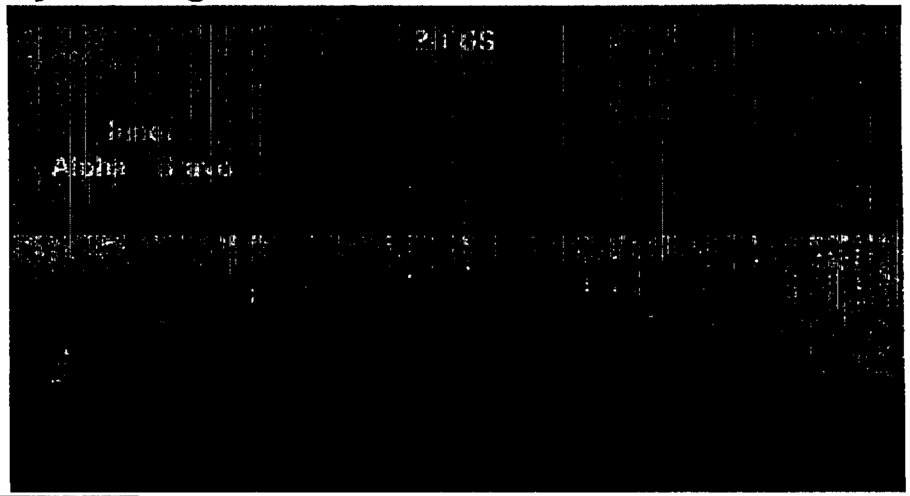
INFORMATION REQUIREMENTS
Info. Available, Missing in Low-Vis.

SYSTEM REQUIREMENTS
Display Elements
Design/Usage Philosophy

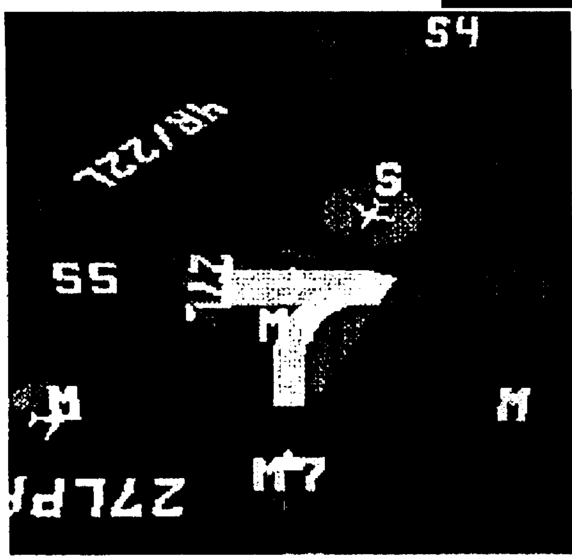
SYSTEM DEFINITION
T-NASA (Taxiway Navigation and Situation Awareness) System
- Scene-Linked HUD Symbology
- Perspective Moving Map Display
- 3-D Audio Ground Collision and Warning

T-NASA SYSTEM

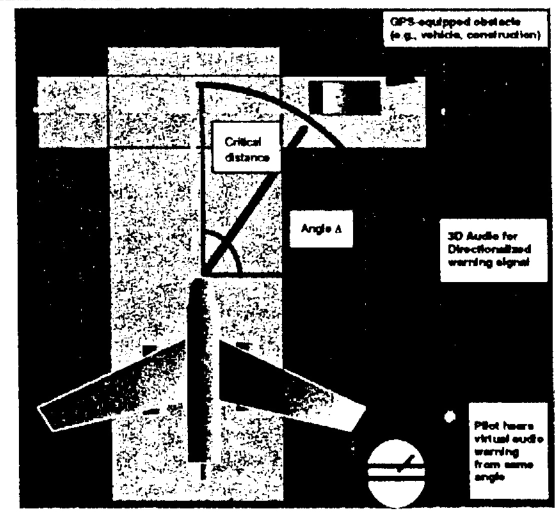
Taxiway Navigation And Situation Awareness System



HEAD-UP DISPLAY (HUD)
SCENE-LINKED SYMBOLOGY



PERSPECTIVE MOVING MAP



3-D AUDIO GROUND COLLISION
AVOIDANCE WARNING (GCAW) SYSTEM

SYSTEM REQUIREMENTS & DEFINITION

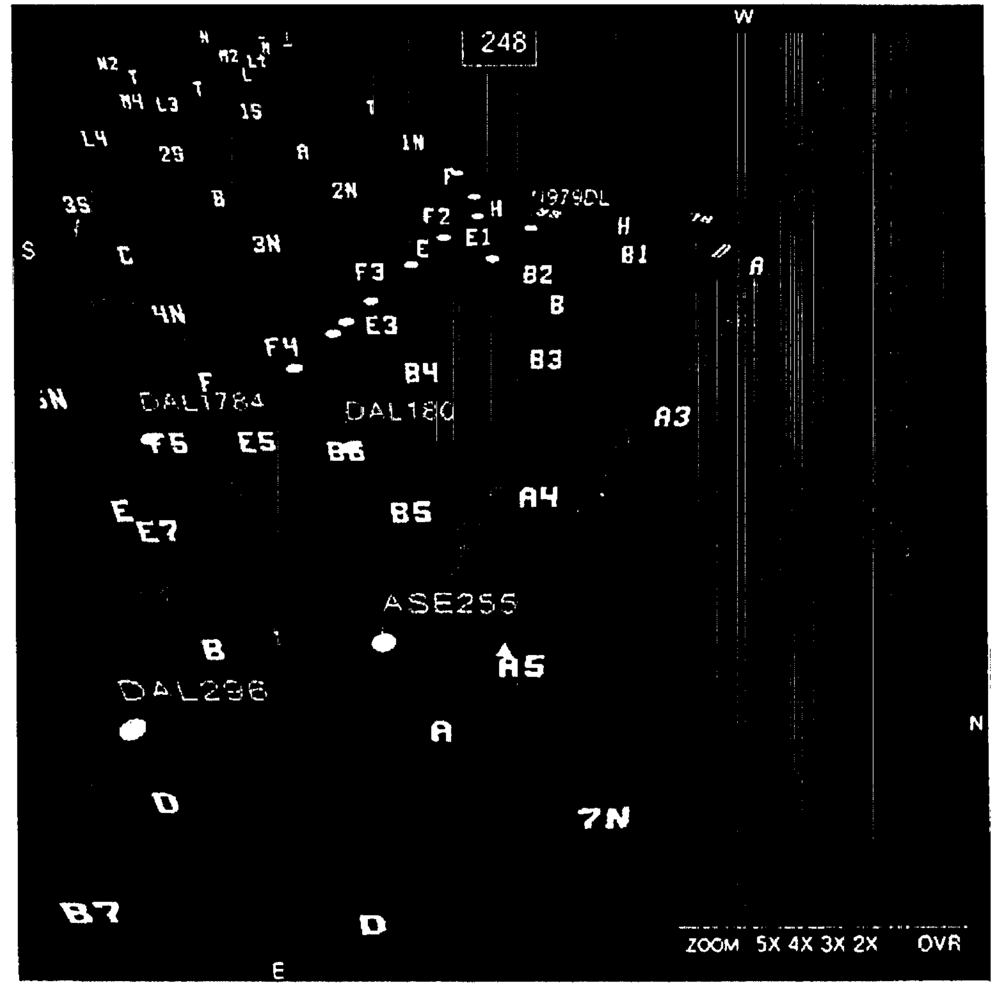
SYSTEM REQUIREMENTS	→	SYSTEM DEFINITION (T-NASA)
• AUGMENTATION OF MISSING GLOBAL AWARENESS CUES Traffic, Route overview	→	• HEAD-DOWN MOVING MAP • 3-D AUDIO TRAFFIC ALERTS
• ENHANCEMENT OF LOCAL GUIDANCE VISUAL CUES Speed cues, Turns	→	• HUD "SCENE-LINKED SYMBOLOGY" • MOVING MAP
• CAPITALIZATION ON PILOT'S TAXI EXPERIENCE Natural, perspective display	→	• HUD "SCENE-LINKED SYMBOLOGY"
• SUPPORT OF "EYES-OUT" TAXI OPERATIONS	→	• HUD "SCENE-LINKED SYMBOLOGY" • HEAD-DOWN MOVING MAP • 3-D AUDIO TRAFFIC ALERTS

Map Research and Design Efforts

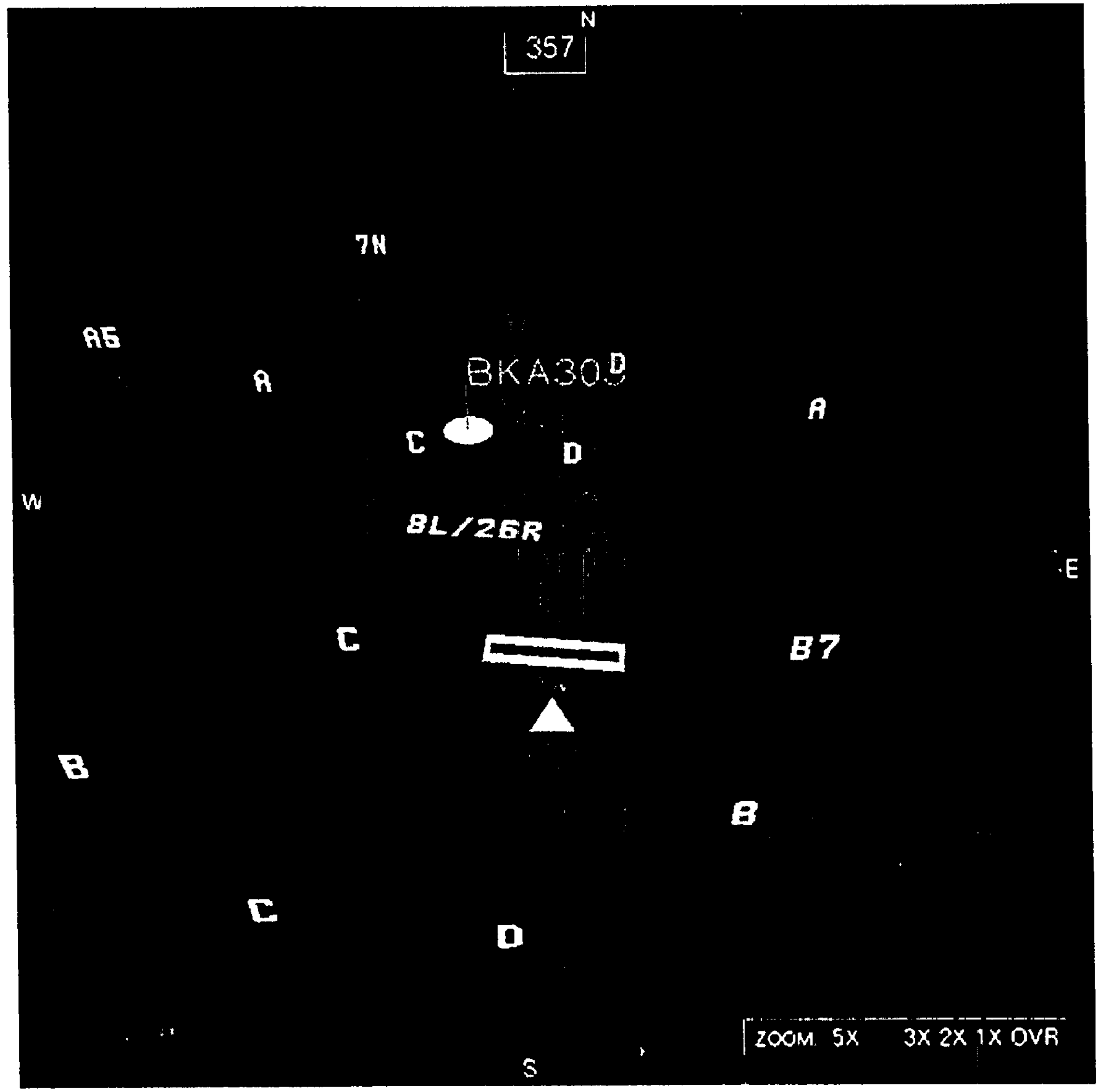
Andre & Mejdal, 1995
- Proof of concept
- Route guidance
- North-up vs. track-up
- Wedge

Andre & Tu, 1996
- 2D vs. 3D, overview
- Icon, labels scaling
- Heading indicator

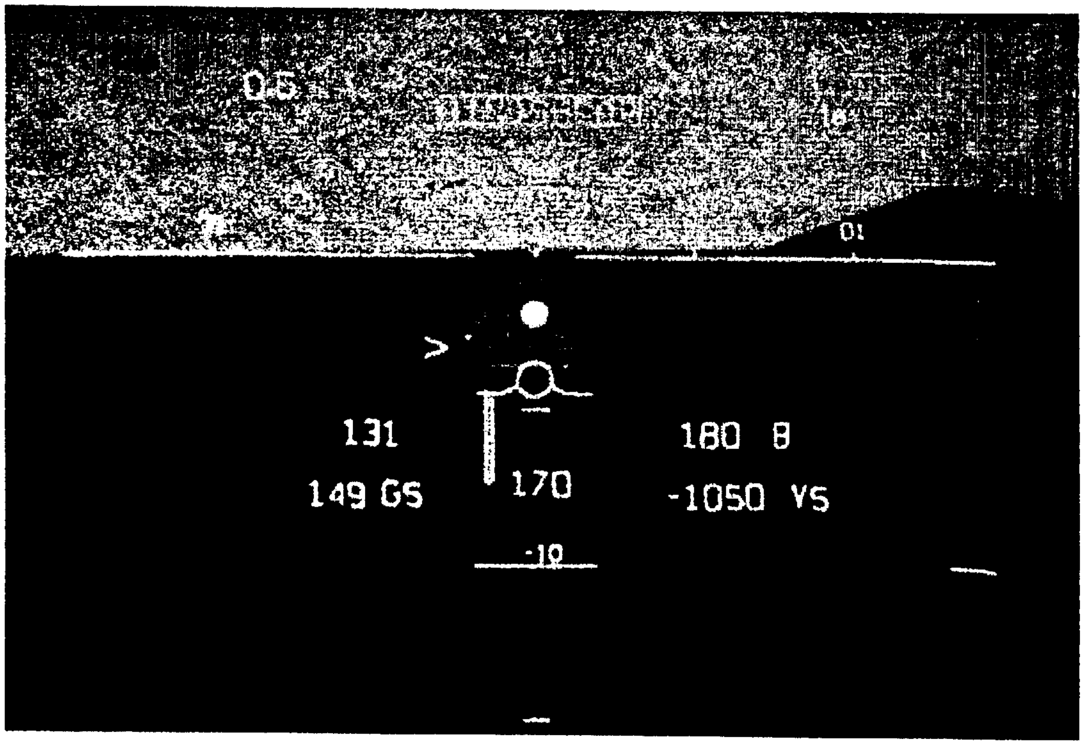
Andre & Graeber, 1997
- Traffic coding
- Inset
- Clearance text / map size



Map Research and Design Efforts



Head-up Display (HUD) Symbology



Advantages
- Not required to visually scan or refocus
- Improved precision landings

Problems
- Accommodation
- Attentional tunneling
  - Runway incursion detection failure
  - Army rotorcraft hover
  - DOD recovery from unusual attitudes

55-06

HUD Design Issues/Principles

Problem: Inefficient processing of *both* HUD symbology and world

Enabling Conditions:

- **Fixed-location symbology visually near the world information (within 8 deg visual angle)**

  Sanford, Foyle, McCann & Jordan, 1993
  Foyle, McCann, Sanford & Schwirzke, 1993

- **Differential motion between fixed-location symbology and world information**

  McCann, Foyle & Johnston, 1993
  McCann, Lynch, Foyle & Johnston, 1993
  Wickens & Long, 1994

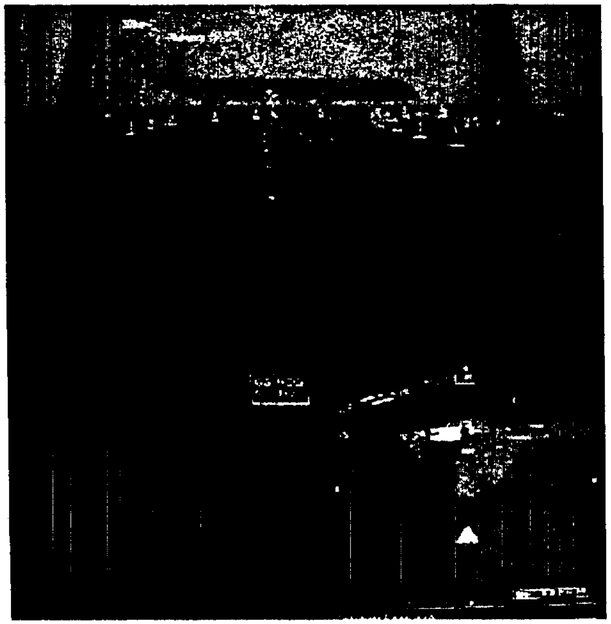
HUD Design Issues/Principles

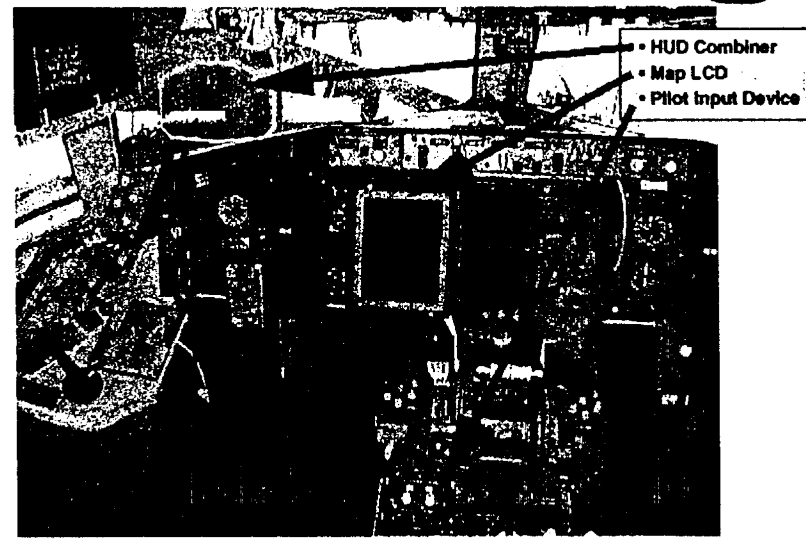
Solutions:

- Require eye movements between world information and HUD symbology
- "Scene-linked Symbology" -- ***Project virtually*** into the world the HUD symbology Foyle, Ahumada, Larimer & Sweet (1992)

- Scene-linked
- Ground speed, drift, look-ahead cues
- Ground speed
- Turn "countdown" warnings
- Location text information
- Turn signs w/ true angle
- Route marker cones

T-NASA: Taxiway Navigation And Situation Awareness System





NASA 757 Cockpit with T-NASA displays at ATL

SIMULATION RESULTS --

T-NASA allows pilots to:

- Taxi faster, at speeds near that of daytime good weather conditions (3.2 - 4.5 kts faster, 3.1 min (37%) savings)
- Have better awareness of airport traffic
- Taxi with decreased workload
- Nearly eliminate incorrect turns off of the cleared taxi route (0.33 errors/route Baseline; 0.014 errors/route T-NASA)

FLIGHT TEST RESULTS --

Joint ARC/LaRC/FAA flight test at ATL. Total 53 flights, mostly night flights to simulate low-visibility.

Two NASA test pilots; 4 airline pilots from 4 airlines.

- Confirmed simulation results (No route errors w/ T-NASA, one route error without system, during Baseline)
- Positive pilot comments
- Strong industry interest

Synthetic Vision Challenges

- Human-Centered Design is most important design criteria
- Human-Centered Design is a continuous ***Process*** (Analysis, guidelines, literature, formal evaluation, iteration)
- Hardware, database, declutter, registration, etc. solutions are necessary but not sufficient
- Task analysis and information requirements is essential first step
- Integration into the cockpit (tasks, procedures, information flow) -- not just hardware/software
- Integration into the NAS (roles and procedures)
- Hardware- or capability-driven solution is inappropriate

D. Foyle
NASA ARC

VDO

Synthetic Vision Workshop II
NASA Langley Research Center
Jan. 98

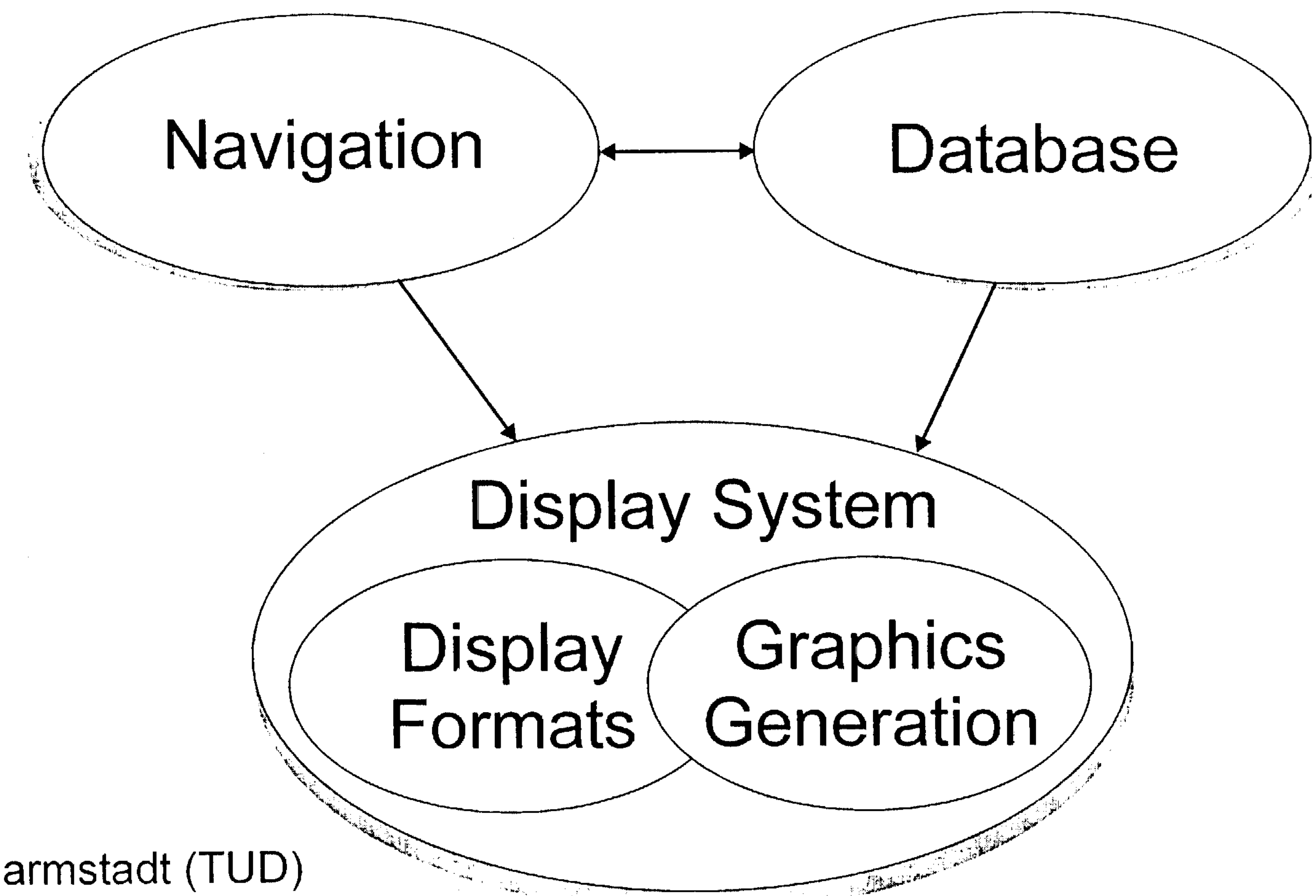
4D-Flight Guidance Displays

VDO-Luftfahrtgeräte Werk
Frankfurt, Germany

Harro von Viebahn

S6-06

Synthetic Vision System

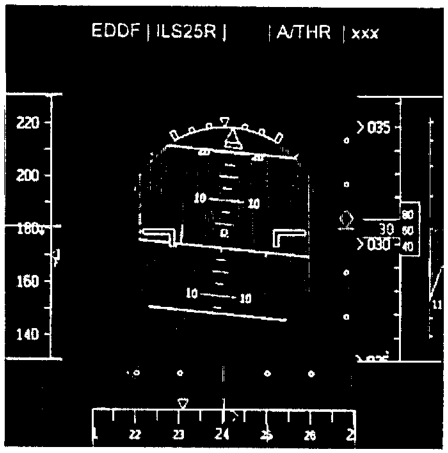


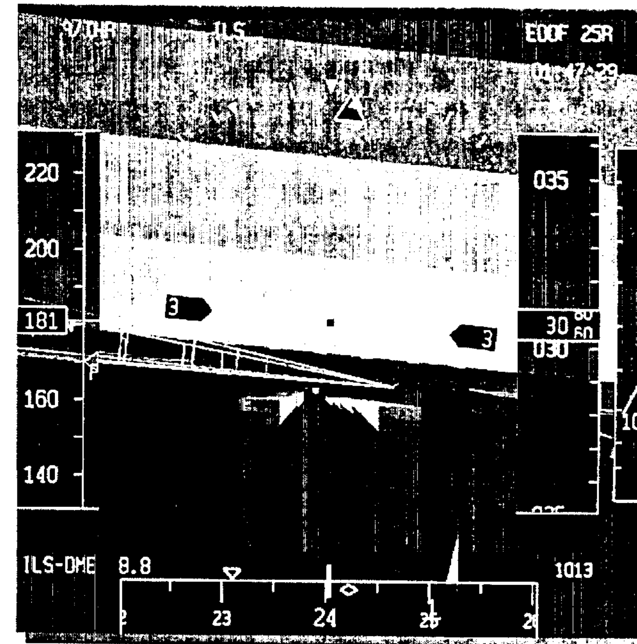
Partners:

University of Darmstadt (TUD)
German Aerospace Center (DLR)
Deutsche Lufthansa (DLH)
USAF Wright Lab.

Goal

VDO





Improvement of safety

Elimination of CFIT

Terrain/obstacle awareness

Improvement of situation awareness

Potential
for future applications

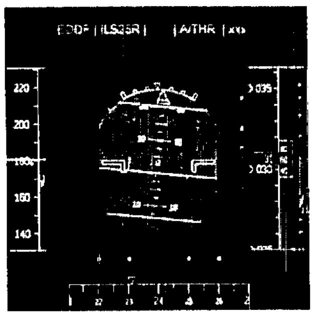
Accurate spatial & on-ground guidance

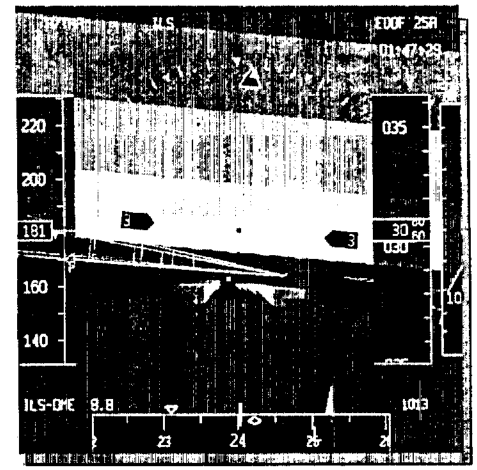
Visualization of (future) flight path & 3D-symbols

Enhancement of operational capabilities

Approach

VDO





Visual information about the 'external' world
- in a 'natural' way
- constant, high image quality
- independent of weather & visibility cond.

Flight guidance information
- 2D parameters (attitude, speed, altitude..)
- 3D 'virtual' elements (ILS, waypoints..)
- prediction

Guidance from gate to gate

Simultaneous Engineering

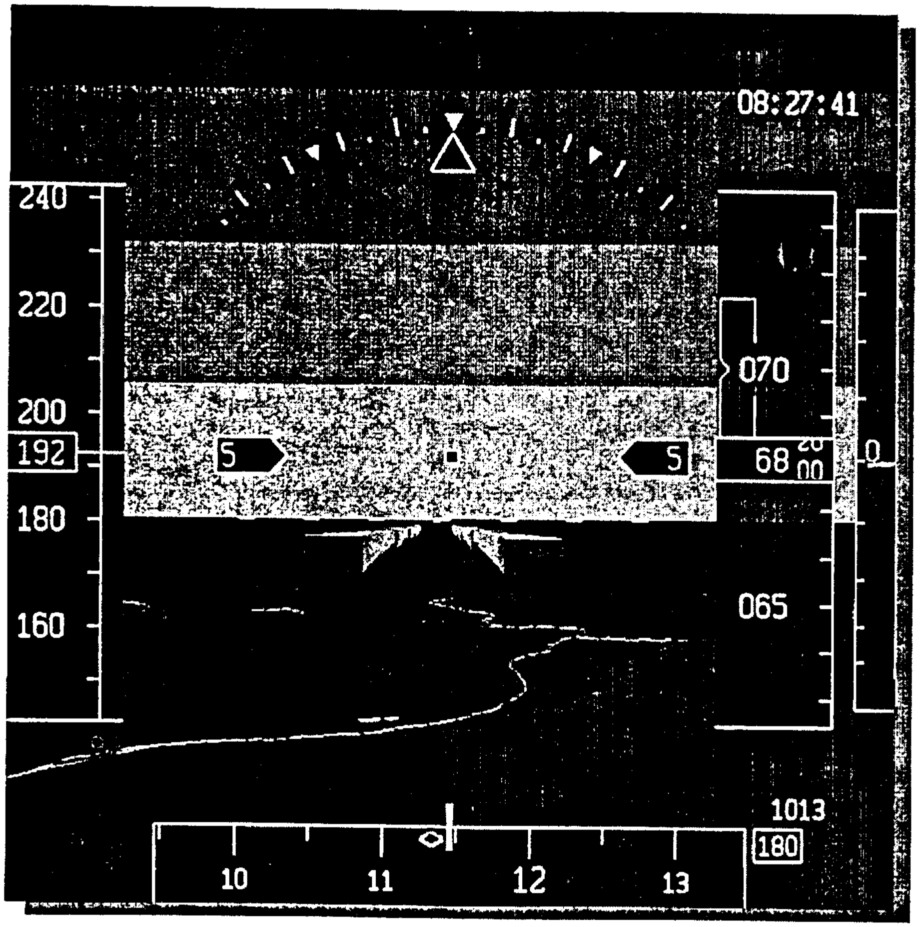
→ Conceptual work and research on display formats

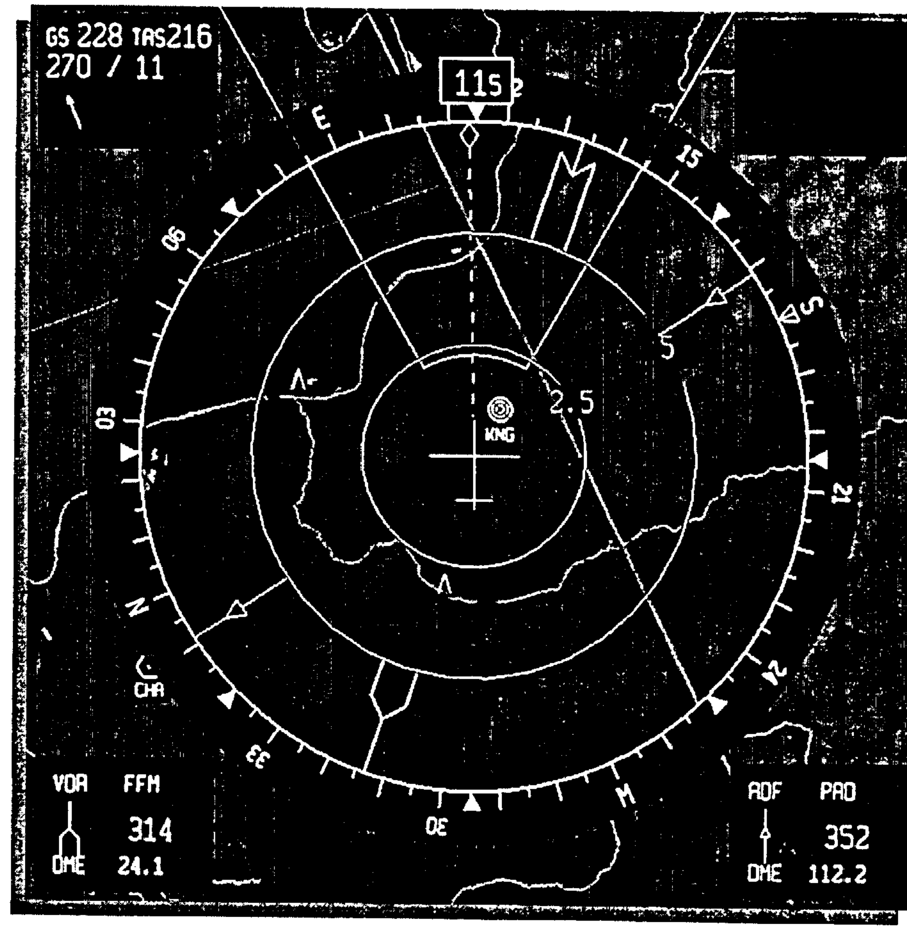
→ Development of avionics equipm.

→ Simulator and flight tests of display formats (PVI)

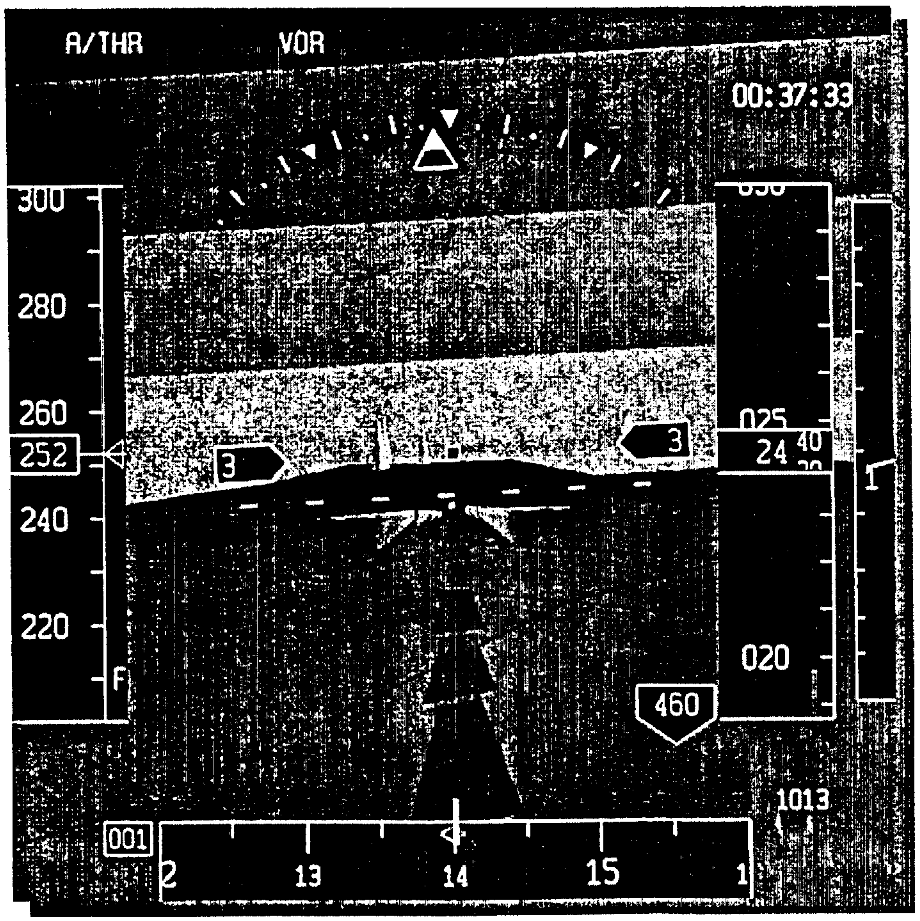
Participation of airline pilots from the very beginning

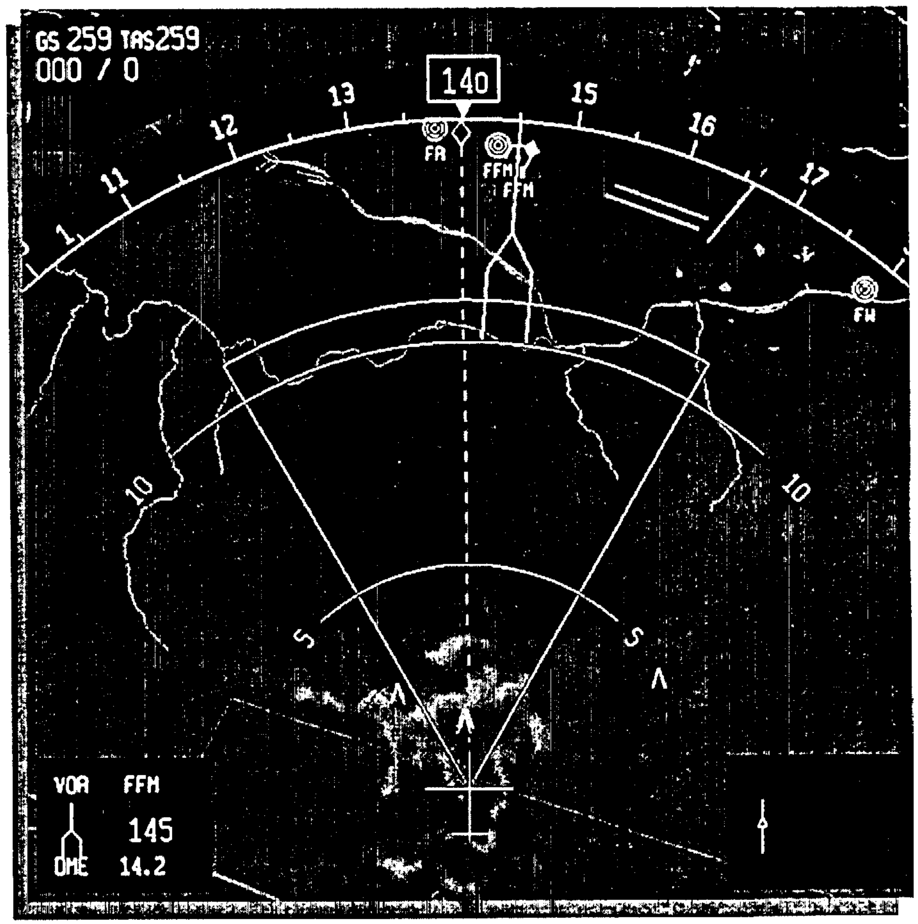
4D-Display & ND

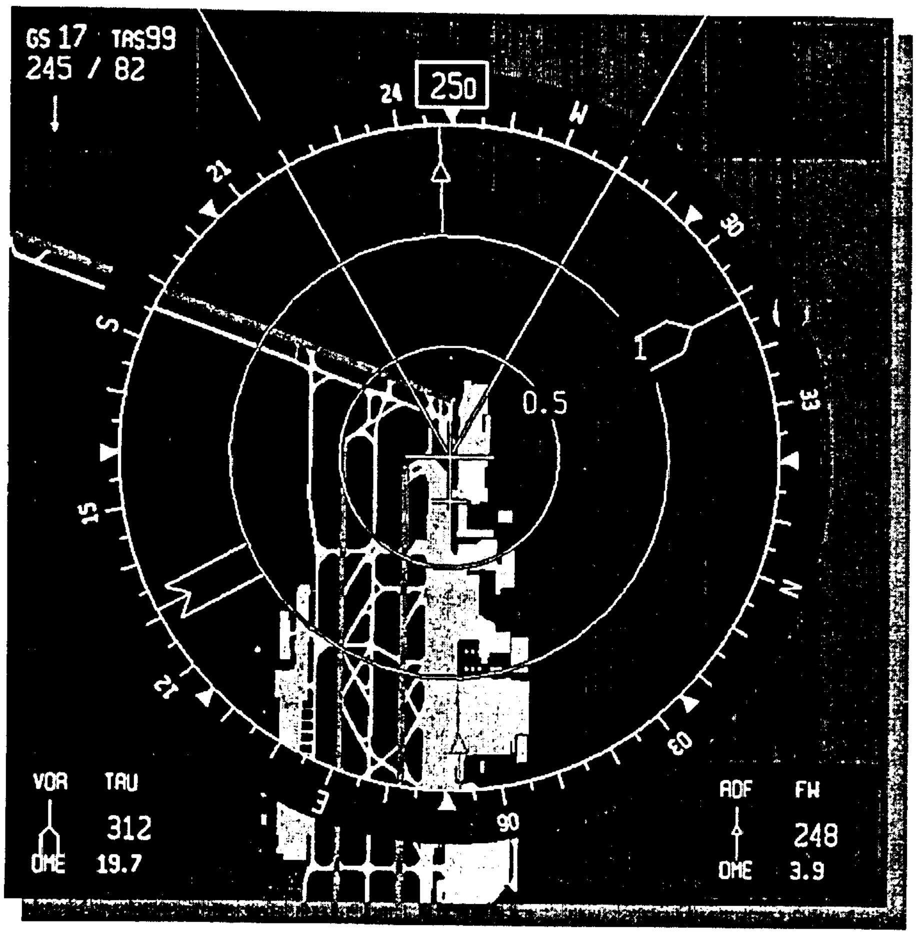


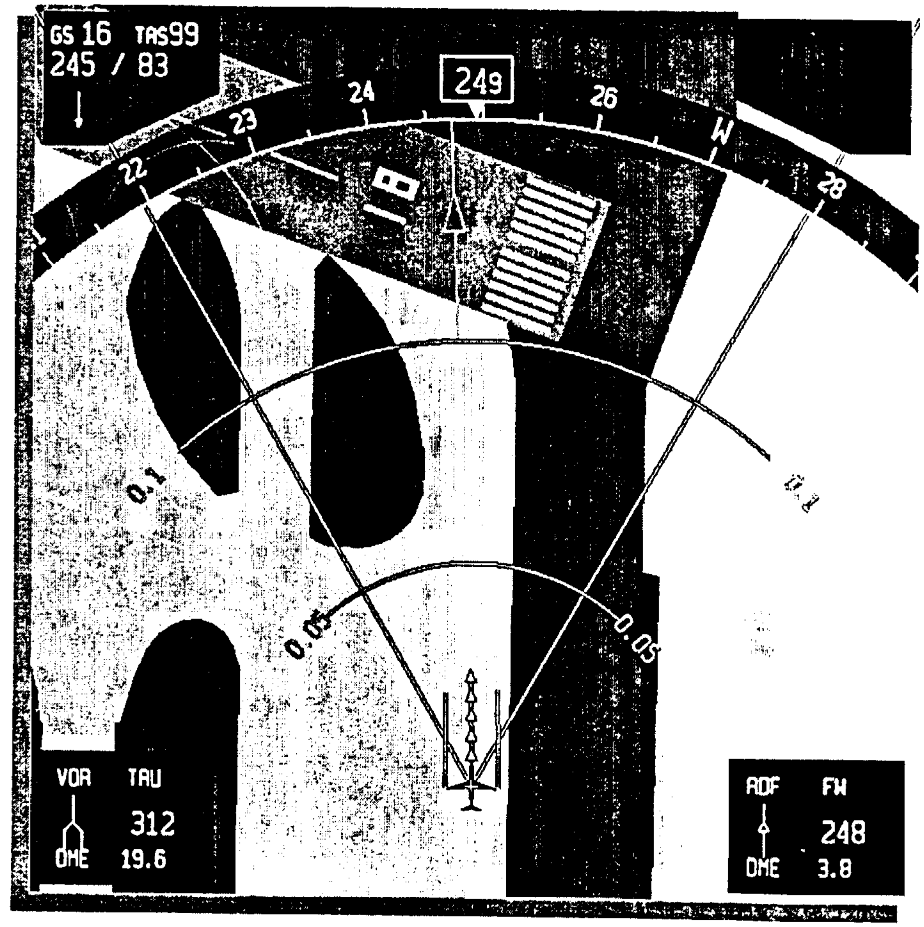


4D-Display & ND






GS 17 TAS99
245 / 82
250
0.5
VOR TRU
312
DME 19.7
ADF FW
248
DME 3.9


GS 16 TAS99
245 / 83
249
0.1
0.05
0.05
VOR TRU
312
DME 19.6
ADF FW
248
DME 3.8

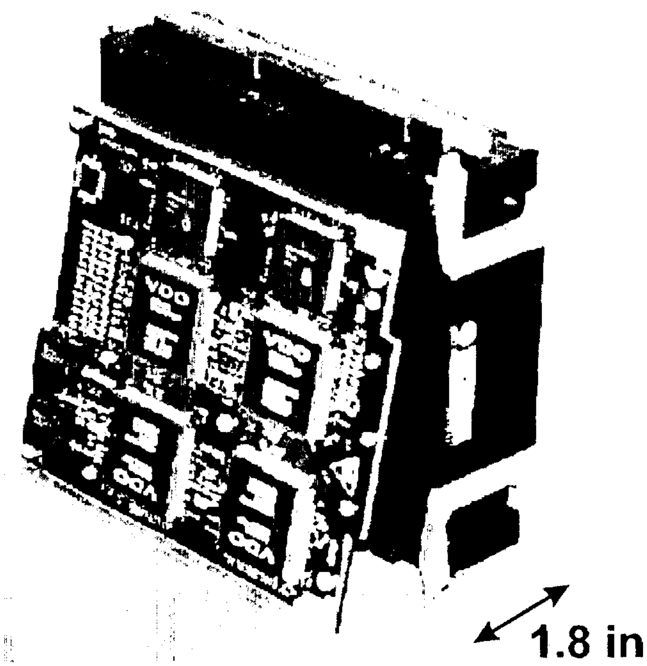
Digital Grafics Module

VDO

Integrated Modular Avionics

- 2D/3D High Performance High Quality Rendering Funktion (ASICs)
- PHIGS Grafic User Interface
- ADA Applicationssoftware
- High Resolution (Color, Screen)
- Comprehensive Antialiasing Functions
- High Density Packaging (SEM-E)
- Highspeed Transmission of digital encoded Videosignal (Fibre Optics)

Evaluation inside USAF WL modular Avionics Testbed and VDO Labs



Digital Grafics Module & Data Preprocessing

VDO

Integrated Modular Avionics

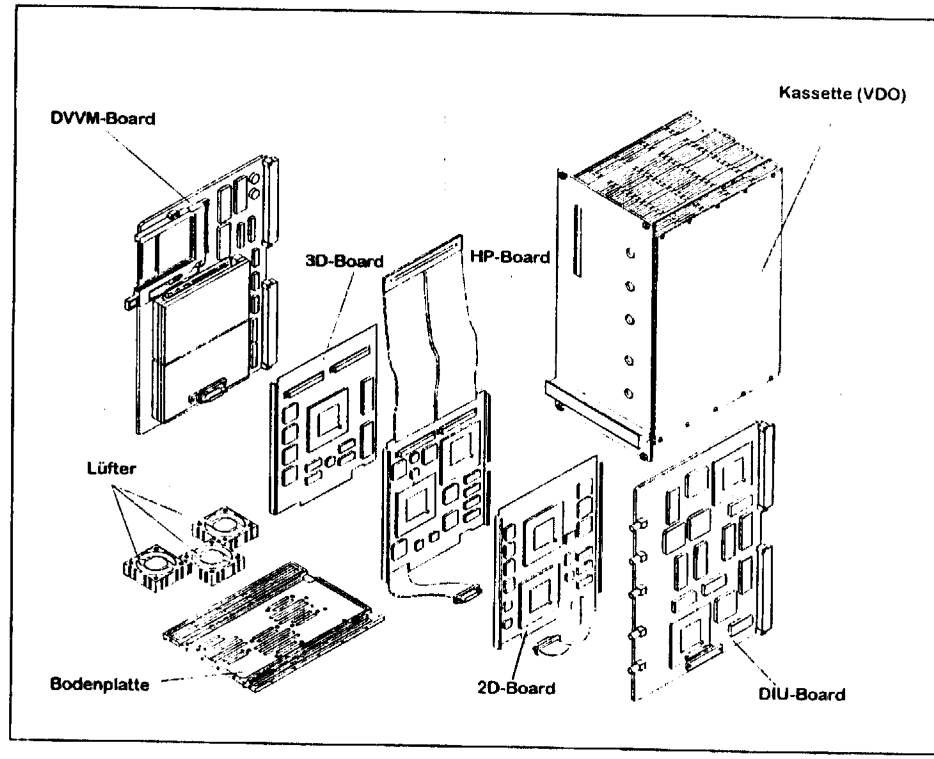
- Addition of intelligent DLMS Mass Data Interface

- Preprocessing of Geographical Data

- VME Architecture
  Interface to Onboard Database

- Low Level Flight Guidance
  Synthetic Vision, Terrain Following

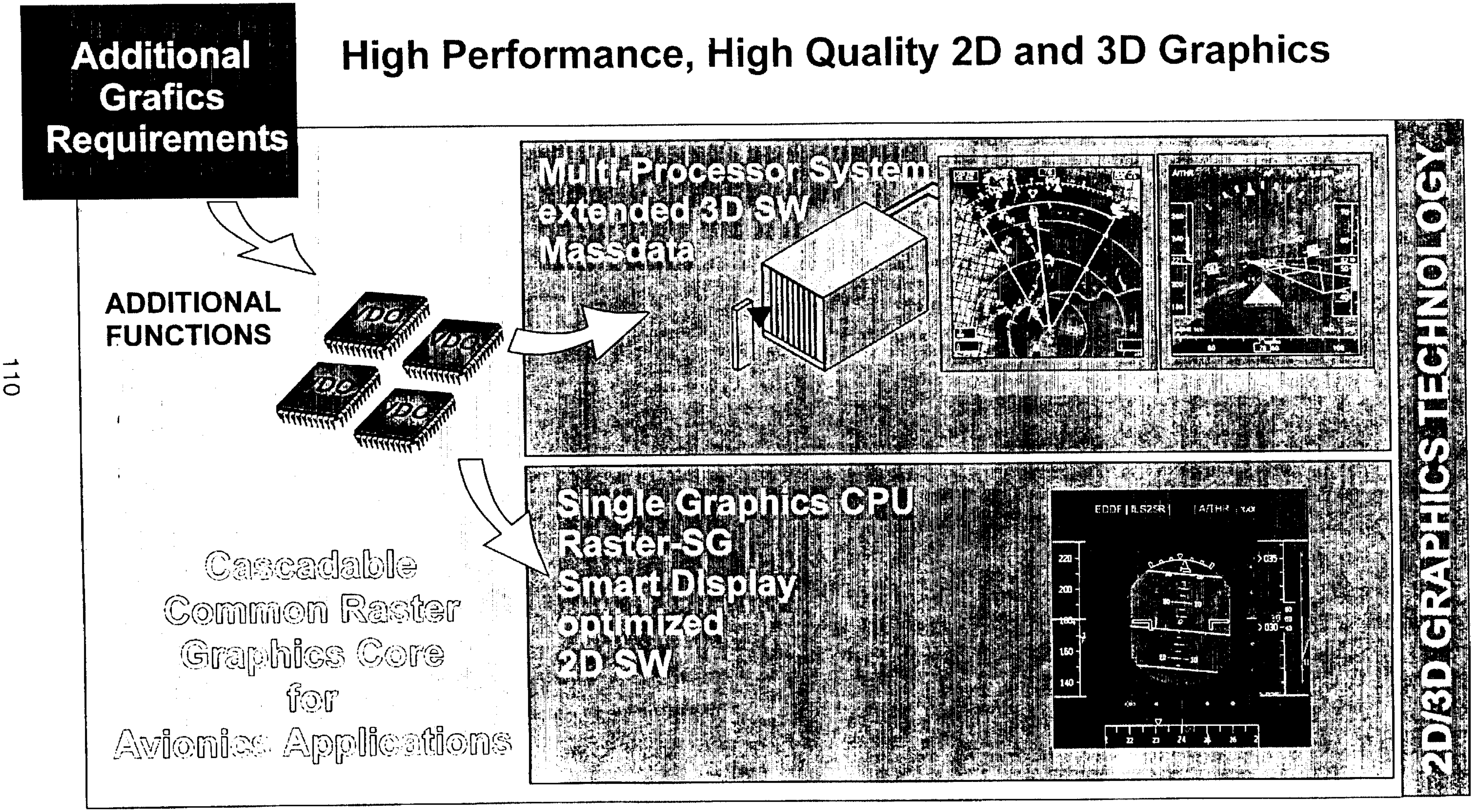
- Integration into a VME Module
  for VME based Demonstrators



Enhanced Raster Graphics Technology

VDO

High Performance, High Quality 2D and 3D Graphics



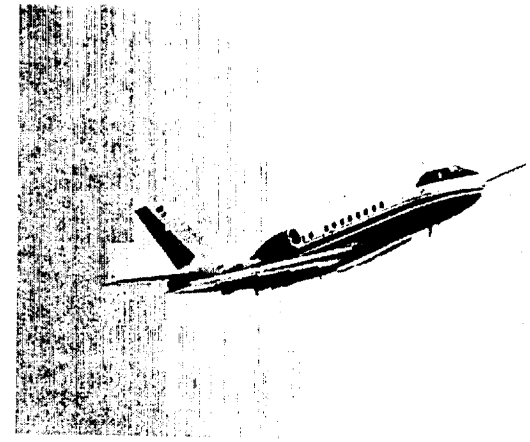
4D-Display Flight Test Programme

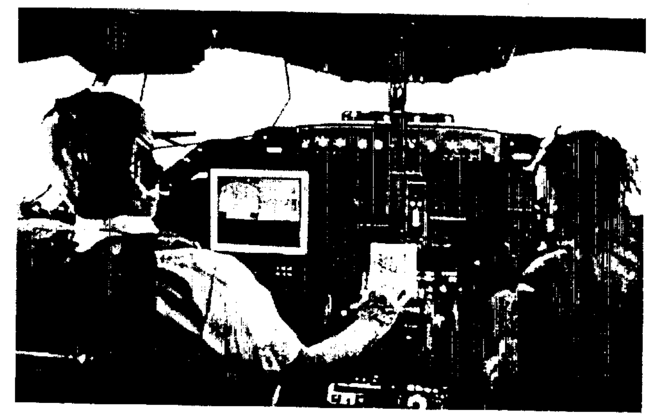
VDO

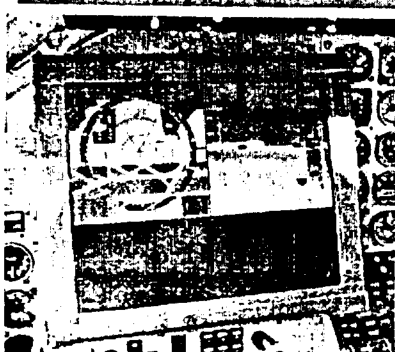
SV system integrated into DLR's ATTAS (VFW614)
5 flight test campaigns (95-97)
> 50 flights with SVS
> 80 flight hours in total
> 35 Pilots from DLR, Lufthansa, VC, Aeroloyd, LBA, Airbus I., German Air Force

Test programmes comprised
- approaches (ILS, standard)
- terrain advisory/avoidance
- enroute navigation
- taxi demonstration
- terrain following
- shifted runway threshold

Partners:
- TU Darmstadt
- DLR
- Lufthansa
- DASA (mil.)







4D-Display Flight Test Programme

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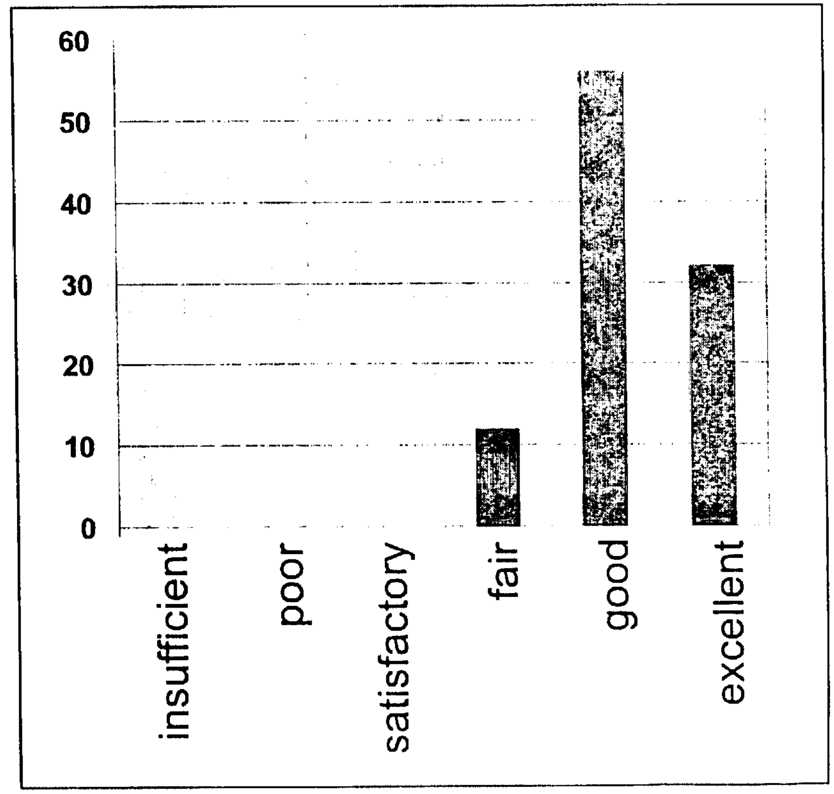
Concept was accepted very well by nearly all pilots !

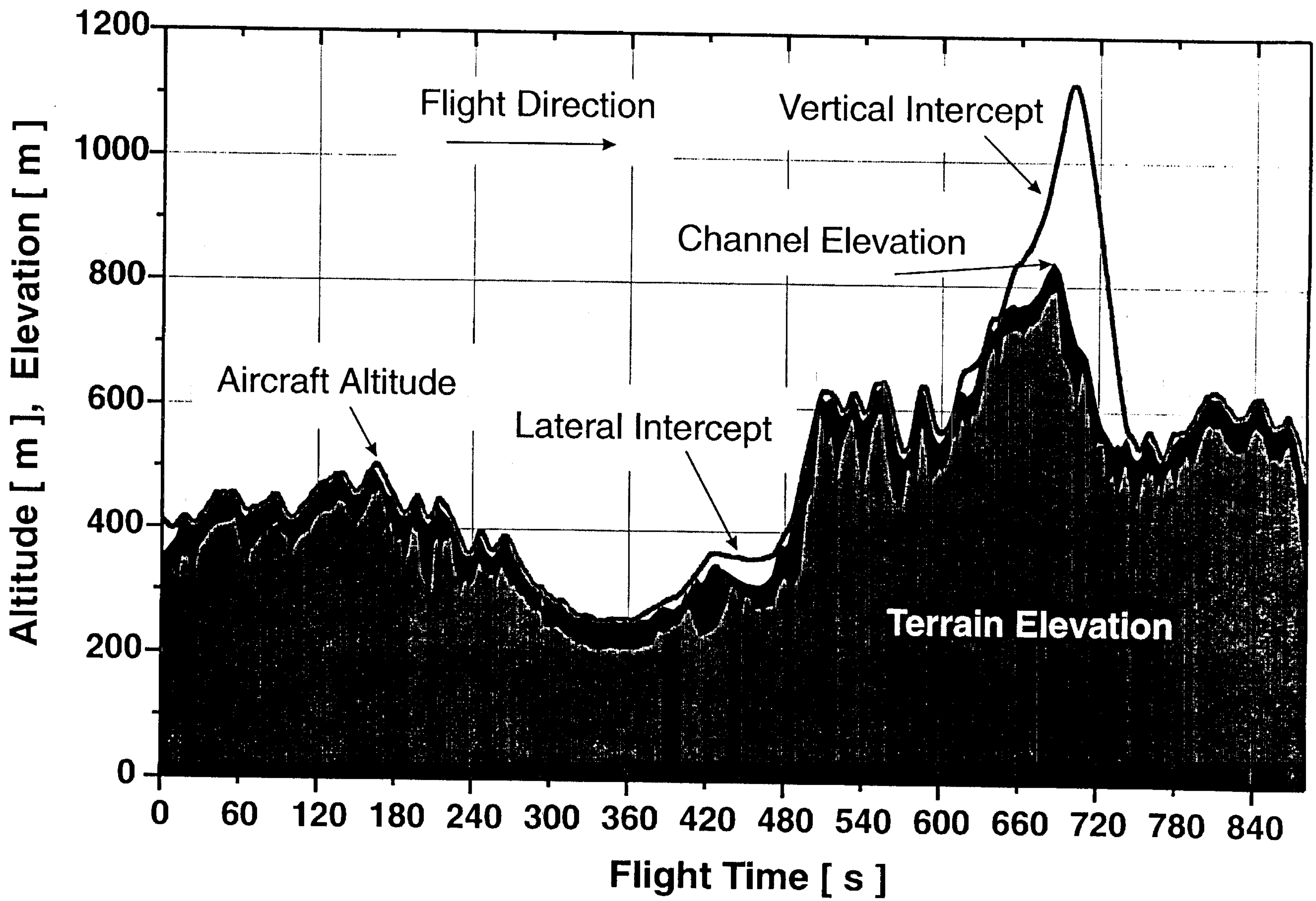
Assessment of functions :

- 👍👍👍 Terrain warning in ND
- 👍👍👍 Terrain representation in ND
- 👍👍👍 Taxi guidance
- 👍👍 Terrain representation in PFD
- 👍👍 Terrain warning in PFD
- 👍👍 Navigation aids in PFD
- 👍👍 Prediction of flight path
- 👍 Channel for straight ILS-approaches

How do you rate your acceptance for this kind of presenting information ?



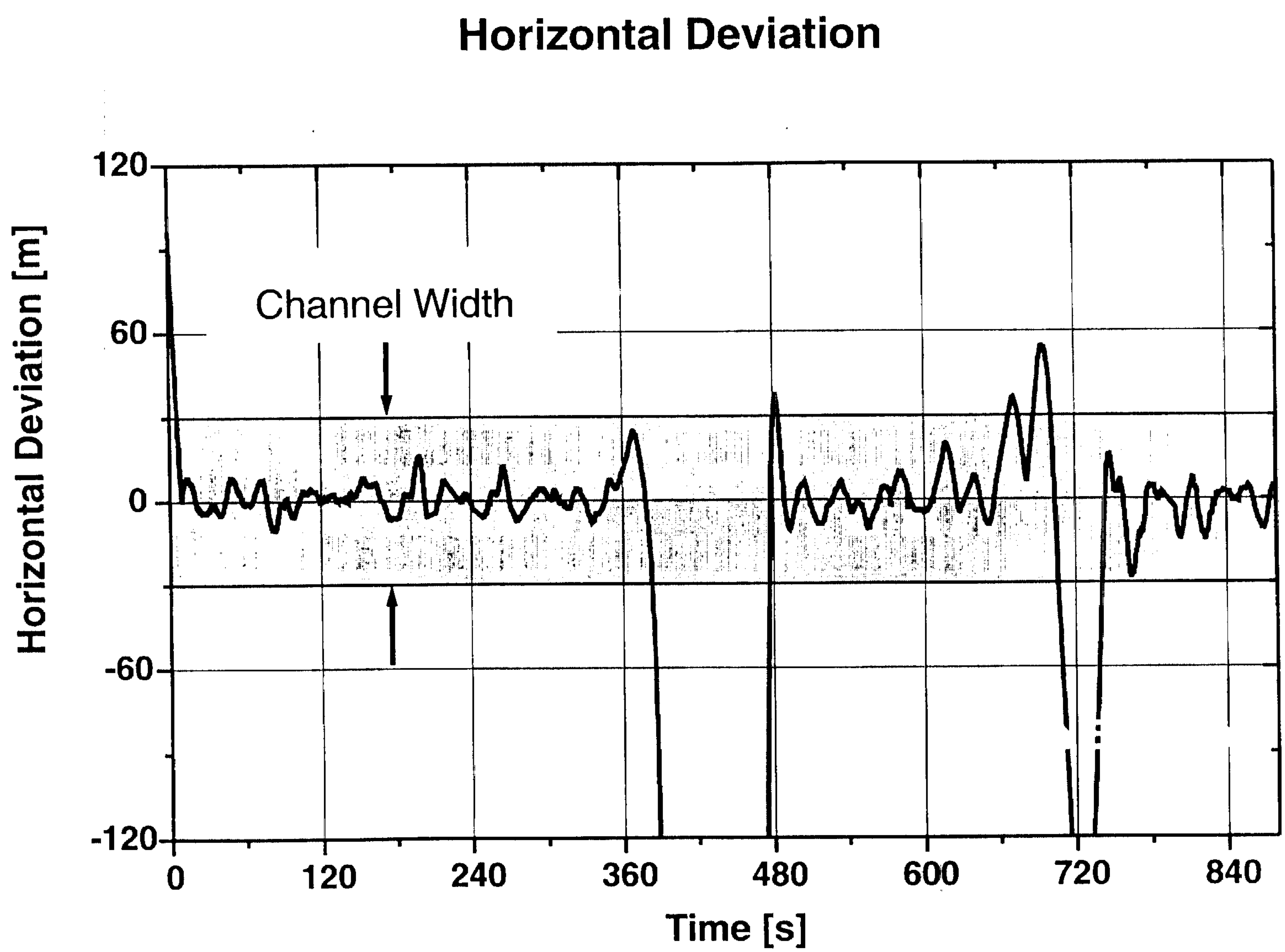
ATTAS Flight with 4D-Display



VDO Luftfahrtgeräte Werk GmbH 60439 Frankfurt

HvV / ATT0502.CDR

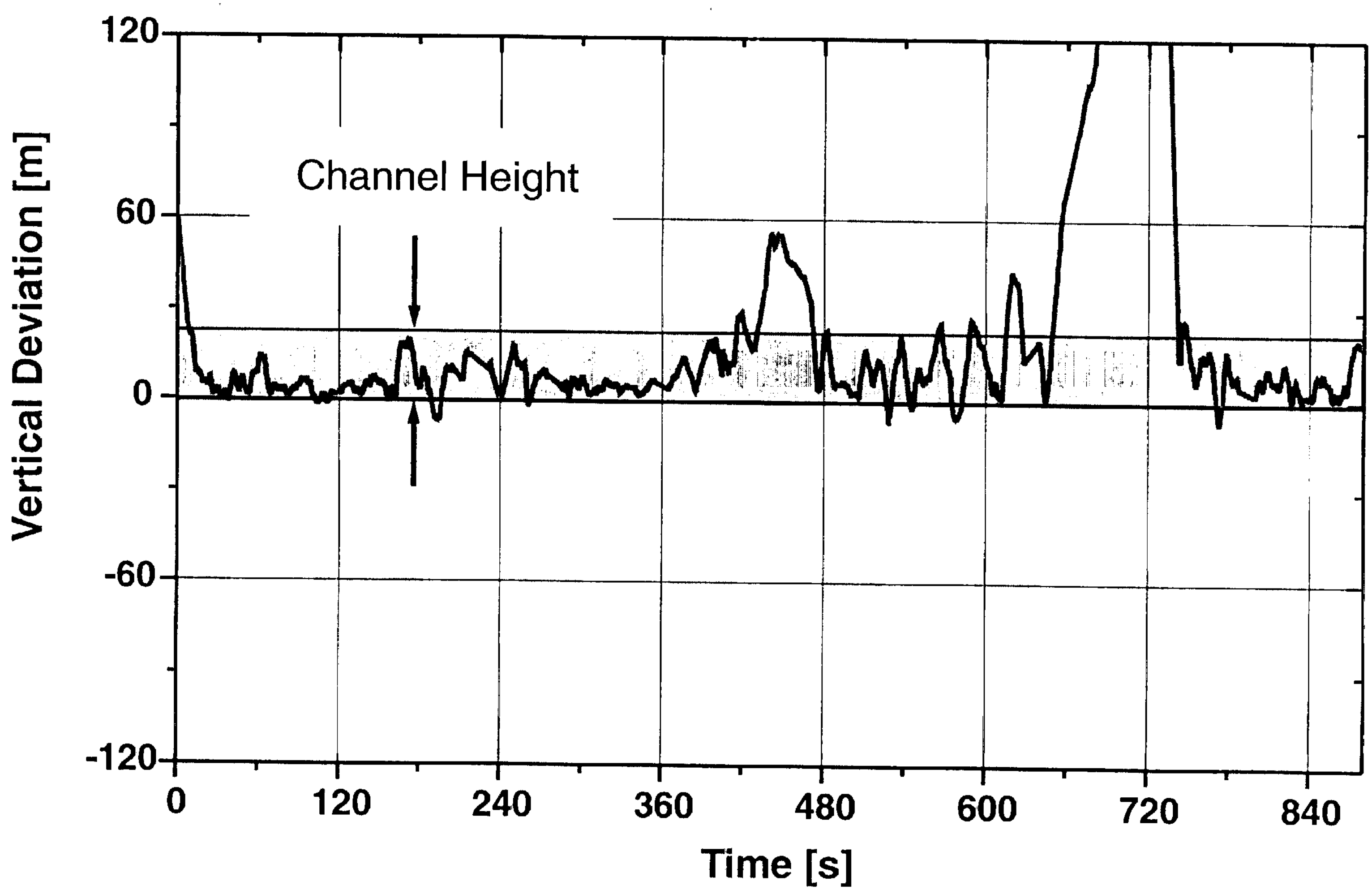
ATTAS Flight with 4D-Display



ATTAS Flight with 4D-Display

VDO

Vertical Deviation



Summary

VDO

SVS / 4D-Display flight tested successfully

PVI: encouring results
proof of concept
well accepted by pilots

Avionics: first prototype available
development of second generation
in progress

Issues:

- certification process
- database
- required navigation performance
- impact on
  - operational procedures
  - pilot training
- attentional issues
- refinement of symbology

VDO

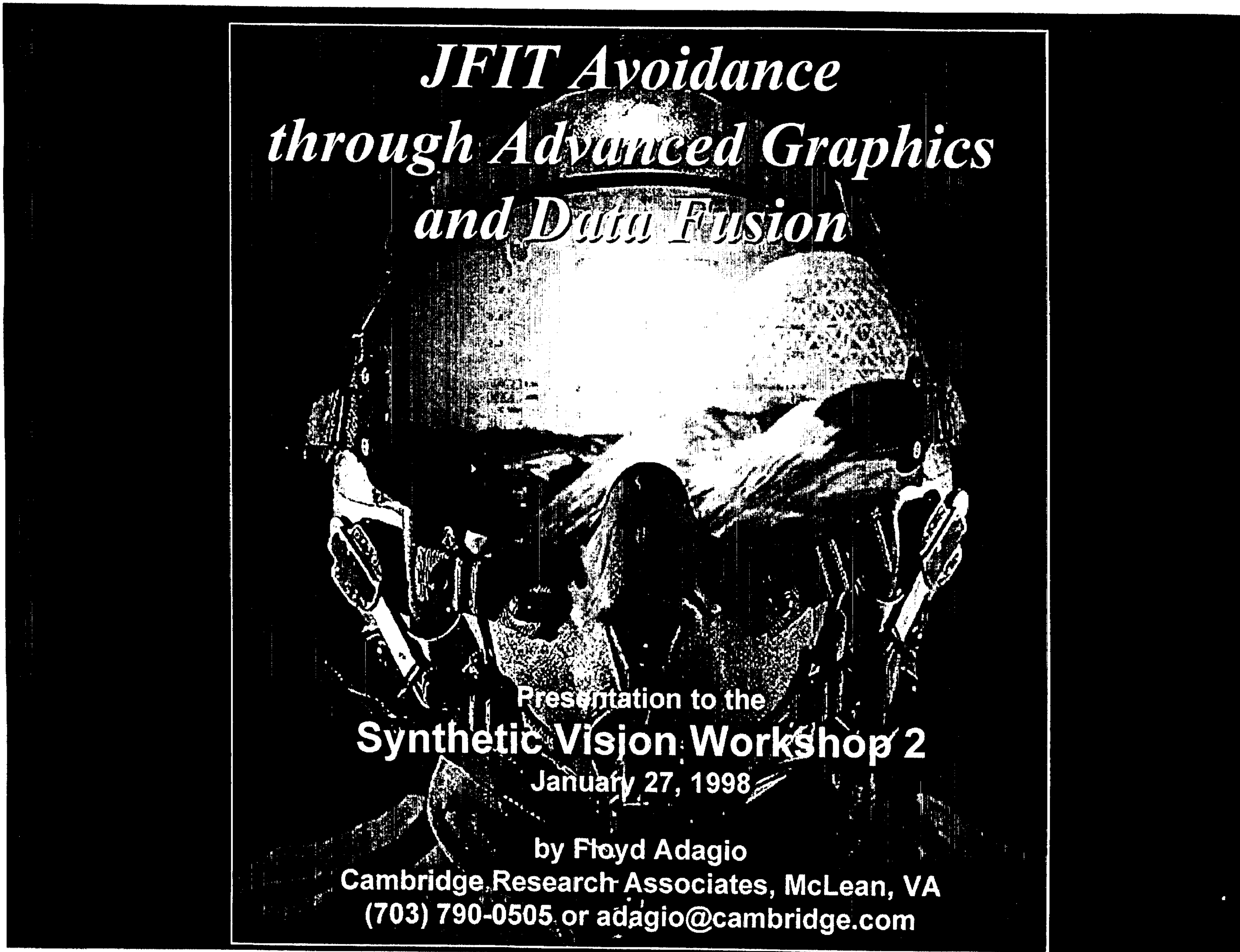
competent partner for 2D/3D graphics/modules for avionics

Statement of an airline pilot (former military test pilot)
after he had flown the ATTAS with the 4D-Display

'I am convinced that with such a display

most, if not all,

CFIT accidents can be avoided'


JFIT Avoidance
through Advanced Graphics
and Data Fusion
Presentation to the
Synthetic Vision Workshop 2
January 27, 1998
by Floyd Adagio
Cambridge Research Associates, McLean, VA
(703) 790-0505 or adagio@cambridge.com

Overview

Introduction

The Concept

The Team

The Approach

Demonstration

Summary

57-06

Cambridge Research Associates

Cambridge Research Associates

- Mid - 1987 Company Start
- Headquartered in McLean, VA
- Corporate Focus on Visualization Applications for Command, Control, Communication, Computer, Intelligence, Surveillance & Reconnaissance (C4ISR) Systems
- Specialize in:
  - Battle Space Visualization
  - Visualization Based Data Fusion
  - Mission Planning & Rehearsal Visualization
  - In Cockpit Visualization
  - Modeling, Simulation & Analysis
- Primary Customer is DoD

Cambridge Research Associates

Government and Industry Recognized Excellence

SAXBY CHAMBLISS
8TH DISTRICT, GEORGIA
Congress of the United States
House of Representatives

Air Power Caucus Hosts Simulator Demonstration

July 9, 1997

Dear Colleague:

On Wednesday, July 16, the Air Power Caucus will host a "hands-on" demonstration of PowerScene, a computerized software system used by U.S. military pilots which helps save lives, time, and resources by providing current field maps, terrain analysis, and visual support in a 3D environment. This means valuable practice runs for our pilots before entering hostile territory.

Members and staff will have an opportunity to view the technology first-hand. You'll even get a chance to "fly" the PowerScene simulator.

This event is sanctioned by the HNSC's Subcommittee on Research and Development and a representative of the USAF, Colonel Steve Clark, will be available throughout the day to answer questions about the program.

Formal presentations of PowerScene will be held at 12:30pm and 3:30pm. Members and staff are encouraged and welcome to personally "fly" the simulator for themselves and can stop by 2212 Rayburn at any time during the day, from 12:00pm to 5:00pm.

If you have any questions concerning the demonstration, please contact Brad Gruehn in my office at 5-6531. If you would like to schedule a flight during the day, please have someone on your staff contact Mr. Clark Nelson at (703)715-3131.

Very truly yours,

Saxby

Saxby Chambliss
Co-Chairman

THIS CERTIFIES THAT

Cambridge Research Associates "Power Scenes"

HAS BEEN SELECTED
AS A RECIPIENT
OF THE
AVIATION WEEK &
SPACE TECHNOLOGY
1996 LAURELS AWARD
FOR OUTSTANDING
ACHIEVEMENT IN THE
FIELD OF
Electronics

David M North
EDITOR-IN-CHIEF

Cambridge Research Associates

PowerScene

- 2-D/3-D visualization system
  - exploits digital terrain elevation and imagery
- Scalable system supports for a variety of applications
- Multi-data sources/sensor
- User configurable
- Future
  - Direct, near real-time ingestion of non-orthorectified imagery
  - Automated "stand-up" of imagery contents
  - Visualization and ingestion of multiple sensor types
  - Full-spectrum location-specific objects/features
  - Real-time analysis and visualization of geographical data
  - Online search, browse, & visualization of dispersed geo-database

User Applications

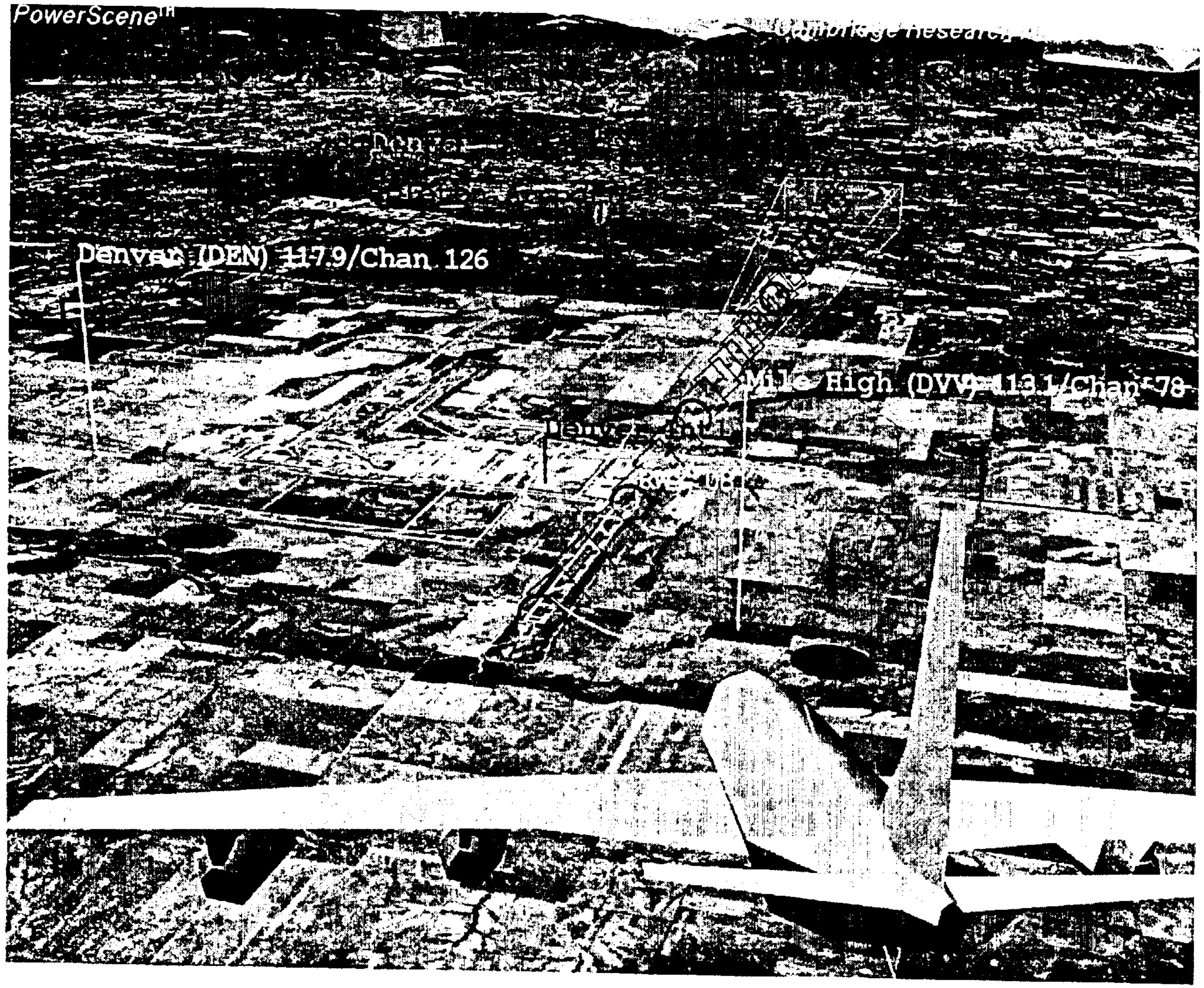
PowerScene has been used for . . .

- Mission Preview - Deliberate Force (Bosnia)
- Mission Rehearsal - Aviano, Vicenza
- Target orientation and Analysis - Deliberate Force, Korea
- Studies and Analysis - Theater Battle Arena
- Joint Strike Fighter Development - Patuxant River
- International Peace Negotiations - Dayton Peace Talks, Lebanon
- Intelligence Analysis and Reporting - NJIMC, NCA, Congress
- Training Simulation - F-15E, F-16, F-18
- National Border Monitoring - Bosnia, Others
- DoD Transportation Planning - Sarajevo
- War Crimes Tribunal - The Hague
- International Media & News Networks - ABC, CBS, NBC, CNN, Discovery Channel, plus Far East, Latin and European Networks
- Public Relations - Air Force Museum, Liberty Science Park

Concept

- Exploit readily available defense technologies
- Enable users at multipe levels with Scalable system configurations
- Employ system engineering approach which provides cost/performance benefit analysis
- Develop concepts of operation and prototype capabilities in constructive, virtual, and flight test environments

PowerScene Demo



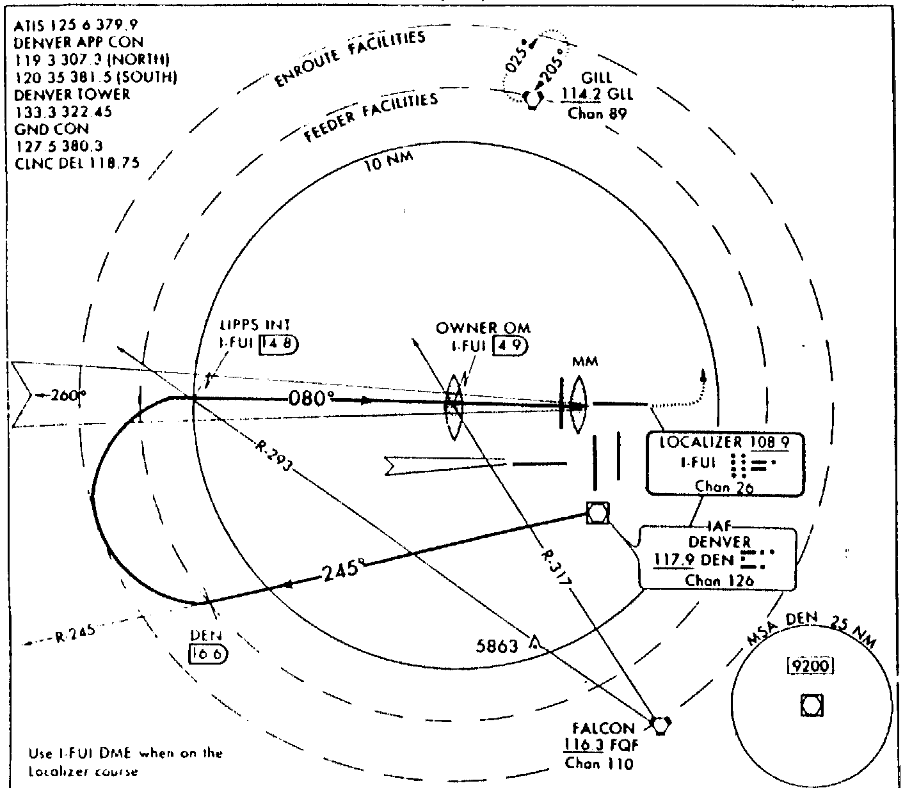
Cambridge Research Associates

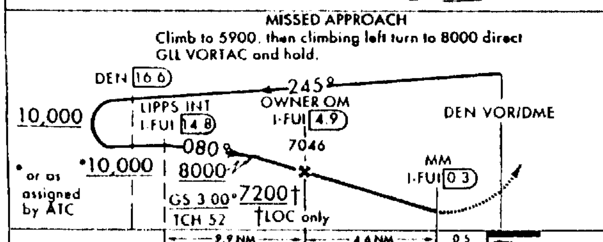
Amdt 2 97254

ILS RWY 8

AL-9077 (FAA)

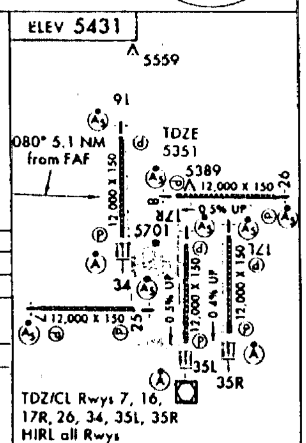
DENVER INTL (DEN)
DENVER, COLORADO





CATEGORY	A	B	C	D
S-ILS 8	5551/24 200 (200-½)			
S-LOC 8	5700/24 349 (300-½)			5700/40 349 (300-¾)
CIRCLING	NA			

Simultaneous approach authorized with Rwy 7.
S-LOC minimums not authorized during simultaneous operations.



TDZ/CL Rwys 7, 16, 17R, 26, 34, 35L, 35R
HIRL all Rwys

FAF to MAP 4.6 NM					
Knots	60	90	120	150	180
Min:Sec	4:36	3:08	2:18	1:50	1:32

ILS RWY 8
Amdt 2 97254

39°52'N-104°40'W

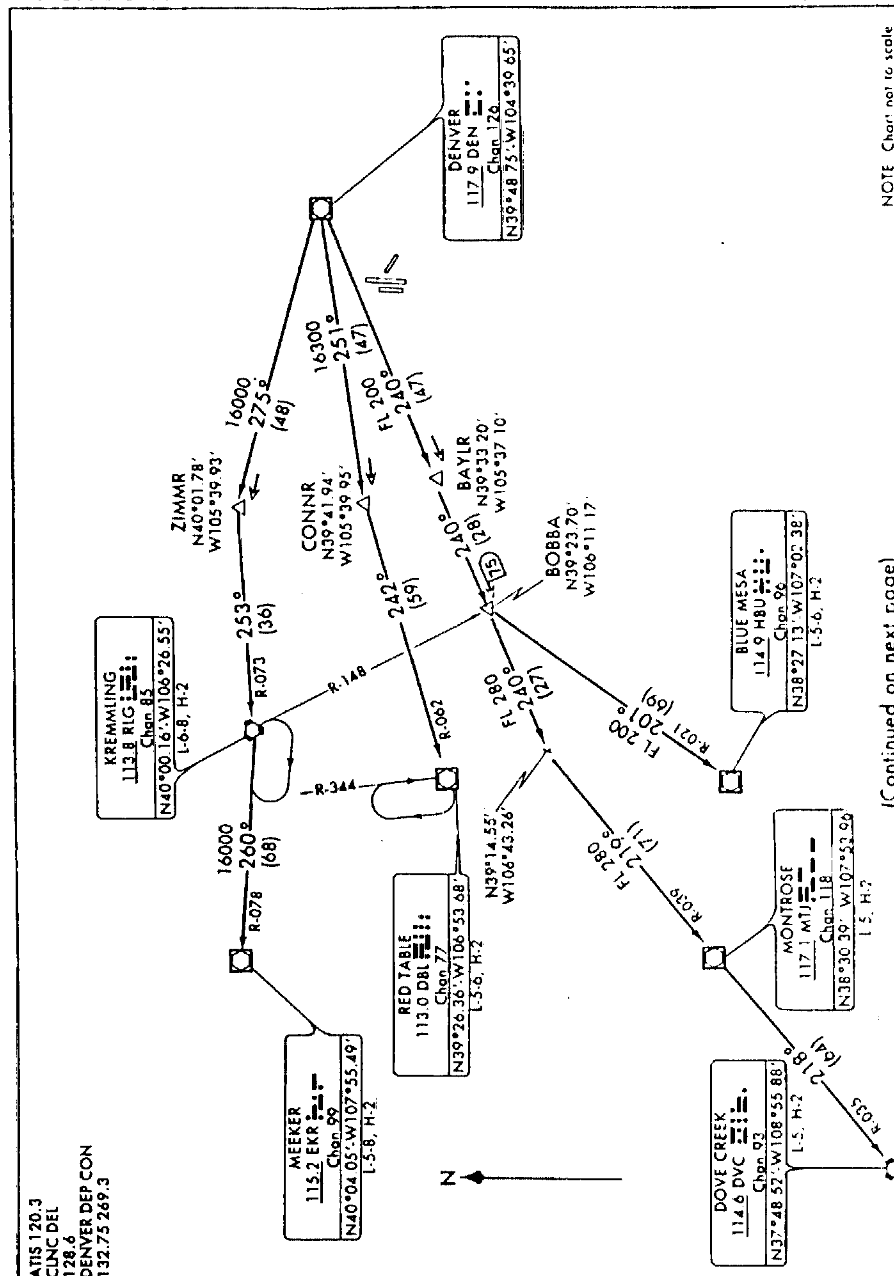
DENVER, COLORADO
DENVER INTL (DEN)

(PILOT NAV) (ROCKI3.DEN) 97198

ROCKIES THREE DEPARTURE

SL-5715 (FAA)

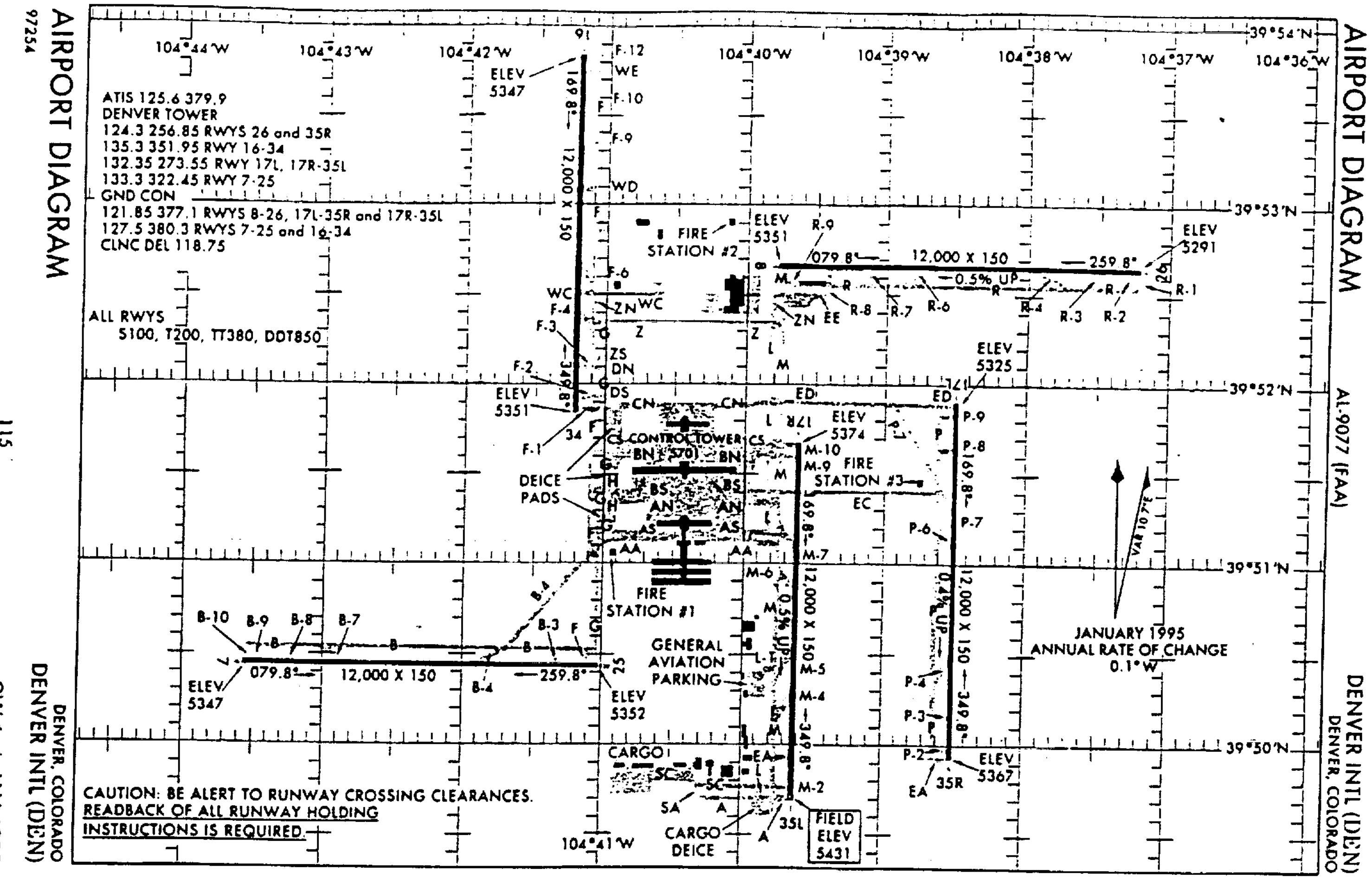
DENVER/CENTENNIAL (APA)
DENVER, COLORADO



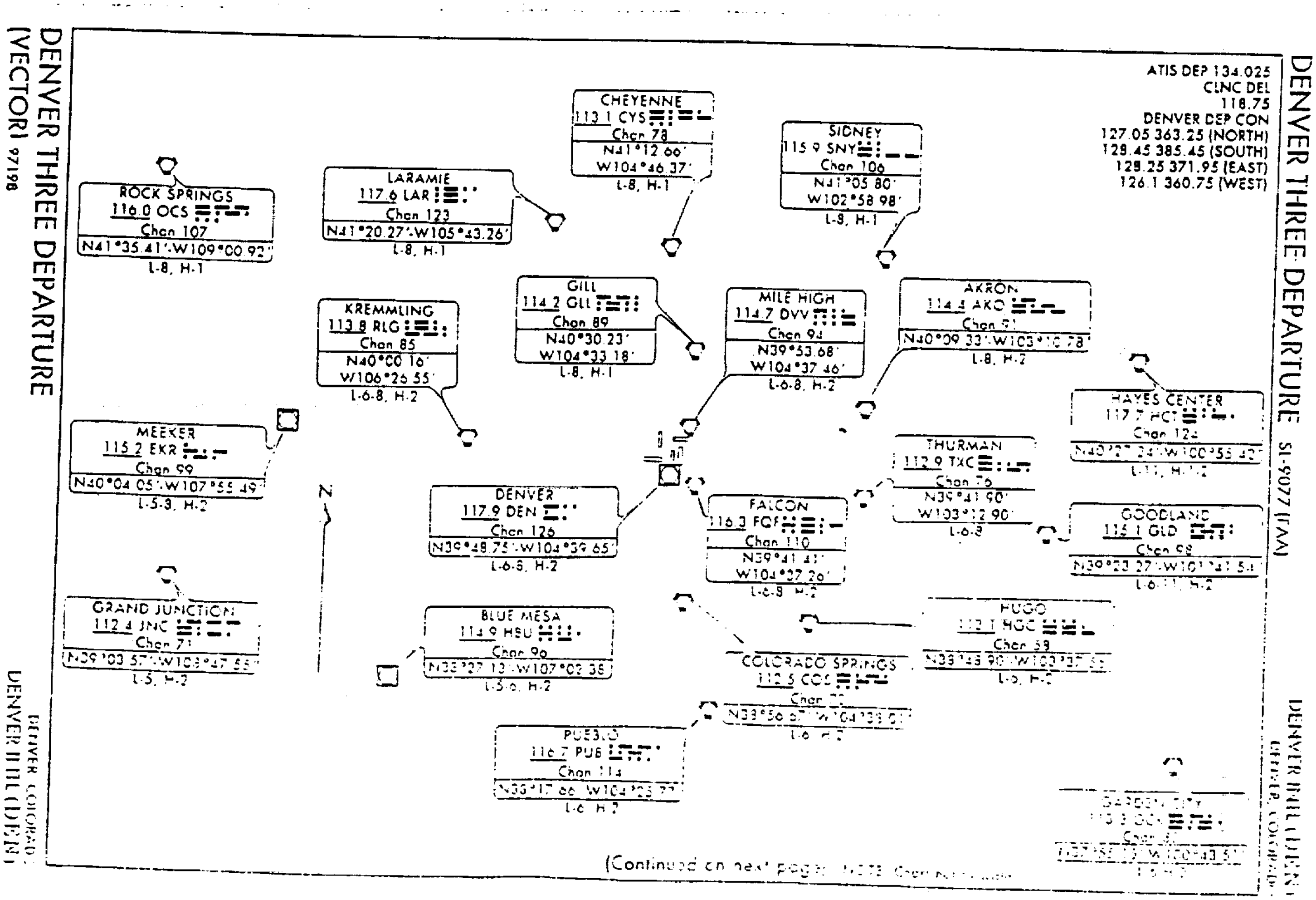
(Continued on next page)

ROCKIES THREE DEPARTURE
(PILOT NAV) (ROCKI3.DEN) 97198

DENVER, COLORADO
DENVER/CENTENNIAL (APA)

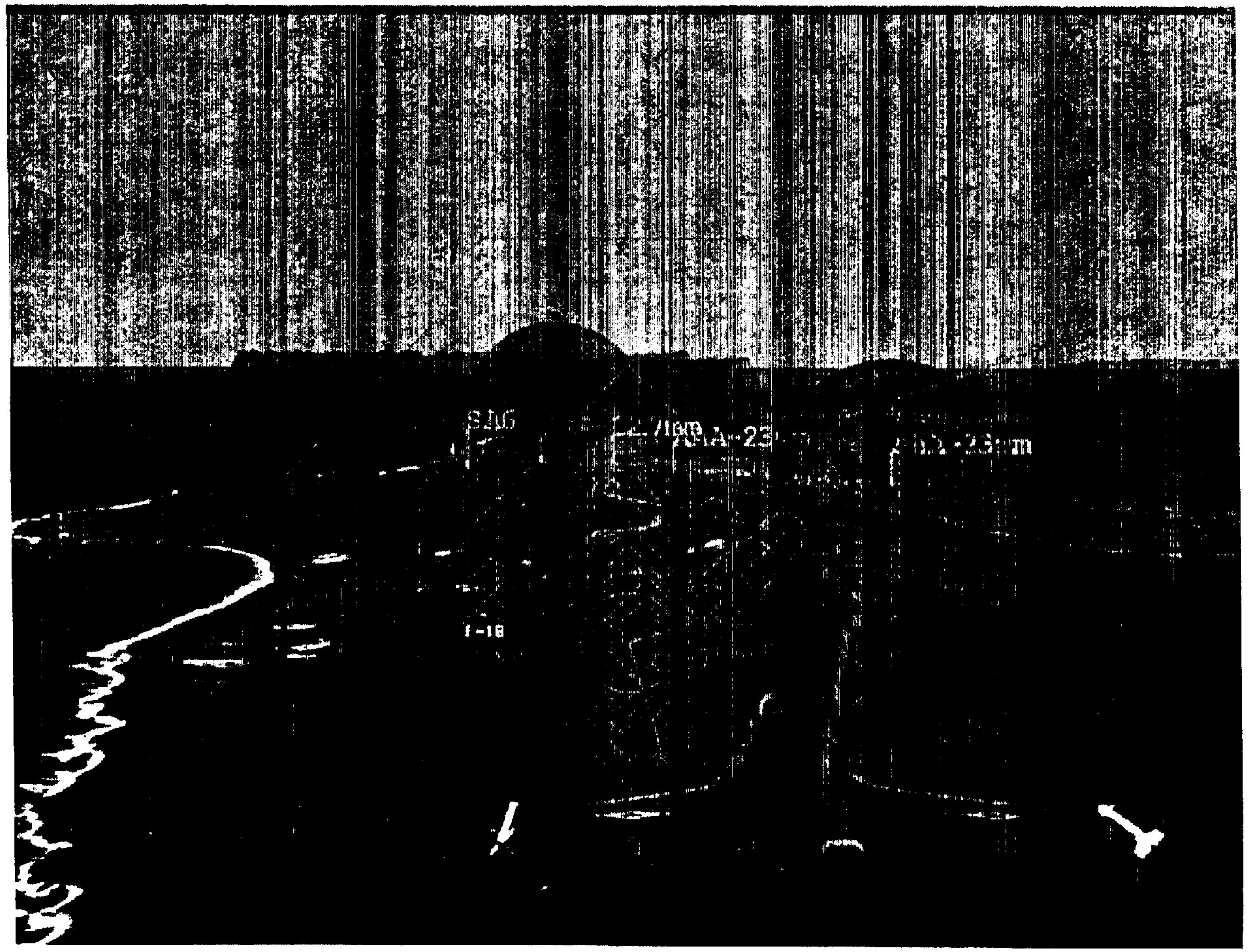


AIRPORT DIAGRAM
97254
AL-9077 (FAA)
DENVER INTL (DEN)
DENVER, COLORADO
SW-1, 1 JAN 1998
115
ATIS 125.6 379.9
DENVER TOWER
124.3 256.85 RWYS 26 and 35R
135.3 351.95 RWY 16-34
132.35 273.55 RWY 17L, 17R-35L
133.3 322.45 RWY 7-25
GND CON
121.85 377.1 RWYS 8-26, 17L-35R and 17R-35L
127.5 380.3 RWYS 7-25 and 16-34
CLNC DEL 118.75
ALL RWYS
5100, T200, TT380, DDT850
JANUARY 1995
ANNUAL RATE OF CHANGE
0.1°W
CAUTION: BE ALERT TO RUNWAY CROSSING CLEARANCES.
READBACK OF ALL RUNWAY HOLDING
INSTRUCTIONS IS REQUIRED.
FIELD
ELEV
5431



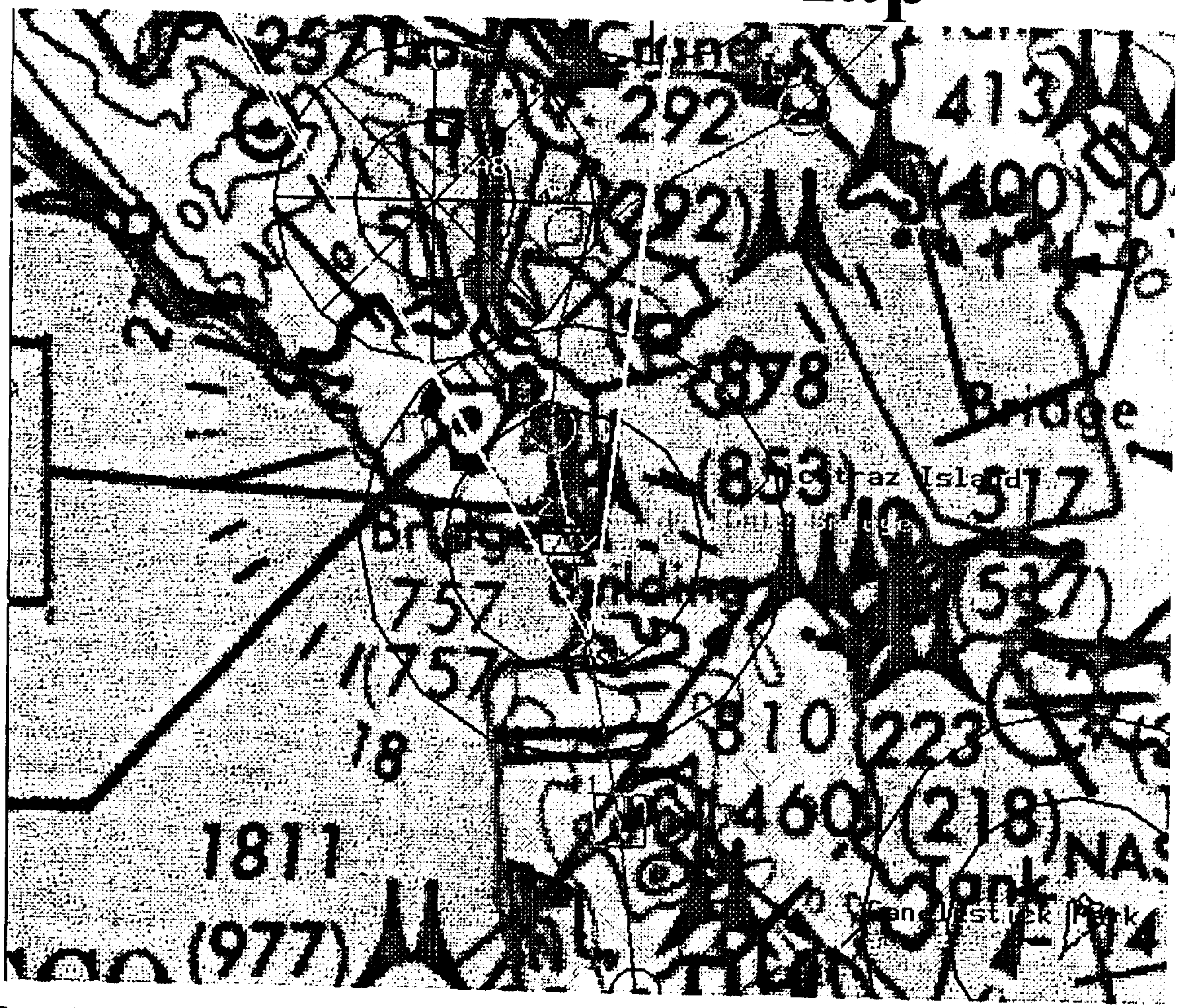
DENVER THREE DEPARTURE
(VECTOR) 97198
SI-9077 (FAA)
DENVER INTL (DEN)
DENVER, COLORADO
ATIS DEP 134.025
CLNC DEL
118.75
DENVER DEP CON
127.05 363.25 (NORTH)
128.45 385.45 (SOUTH)
128.25 371.95 (EAST)
126.1 360.75 (WEST)
CHEYENNE
113.1 CYS
Chan 78
LARAMIE
117.6 LAR
Chan 123
ROCK SPRINGS
116.0 OCS
Chan 107
SIDNEY
115.9 SNY
Chan 106
GILL
114.2 GLL
Chan 89
KREMMLING
113.8 RLG
Chan 85
MILE HIGH
114.7 DVV
Chan 94
AKRON
114.4 AKO
MEEKER
115.2 EKR
Chan 99
DENVER
117.9 DEN
Chan 126
FALCON
116.3 FQF
Chan 110
THURMAN
112.9 TXC
HAYES CENTER
GOODLAND
GRAND JUNCTION
112.4 JNC
BLUE MESA
COLORADO SPRINGS
HUGO
PUEBLO
116.7 PUB
GARDEN CITY
(Continued on next page)

PowerScene Imagery



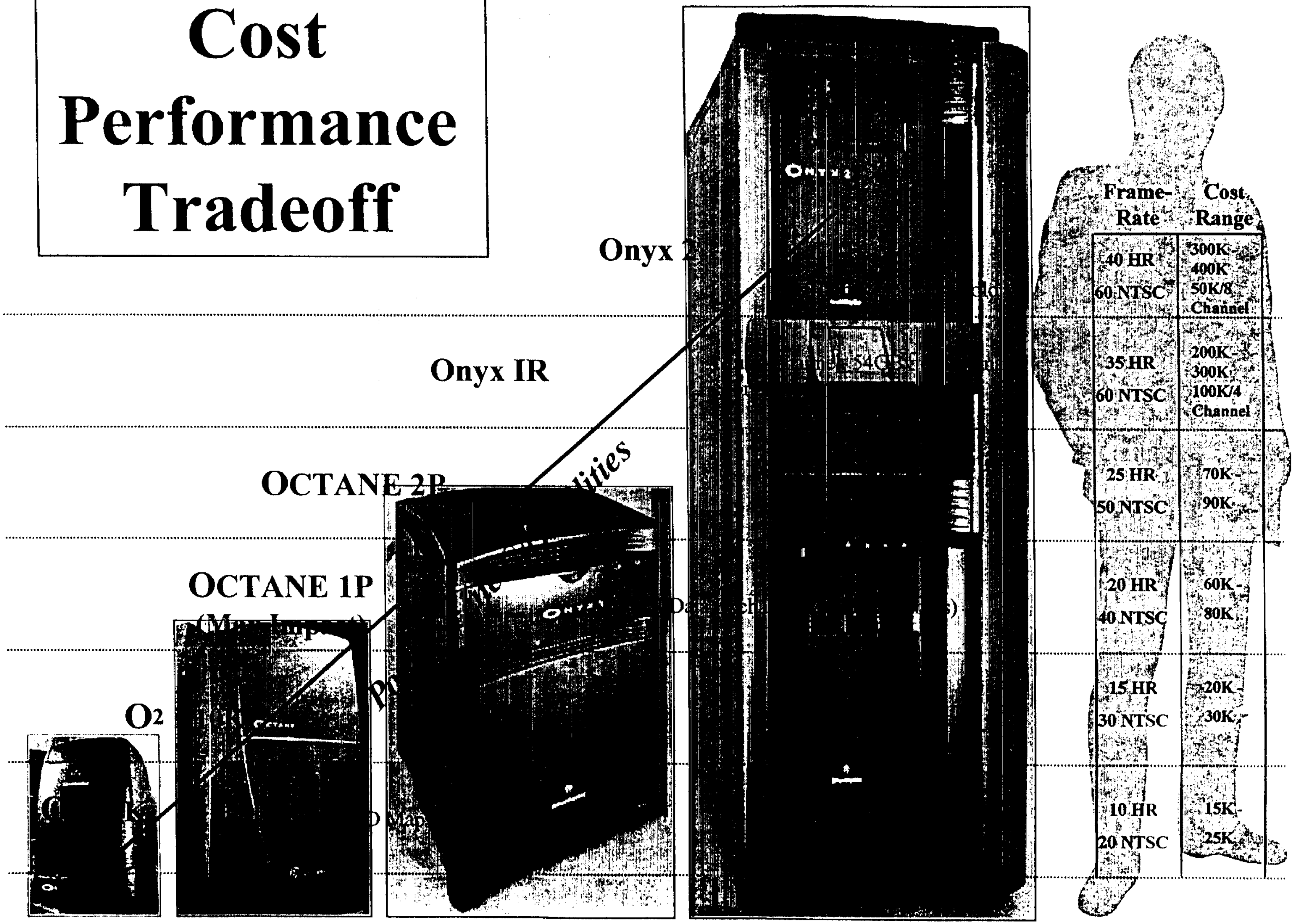
Cambridge Research Associates

PowerScene Map



Cambridge Research Associates

Cost Performance Tradeoff



Frame-Rate	Cost Range
40 HR 60 NTSC	300K-400K 50K/8 Channel
35 HR 60 NTSC	200K-300K 100K/4 Channel
25 HR 50 NTSC	70K-90K
20 HR 40 NTSC	60K-80K
15 HR 30 NTSC	20K-30K
10 HR 20 NTSC	15K-25K

The Team

FAA

MITRE

NASA

Cambridge Research Asscoiates
System Engineering
SA Software
C4I connectivity

Synthetic Vision
CRADA

Naval Air Systems Command
MAST Avionics Technologies
Advanced Graphic and Fusion
Open Architecture Hardware

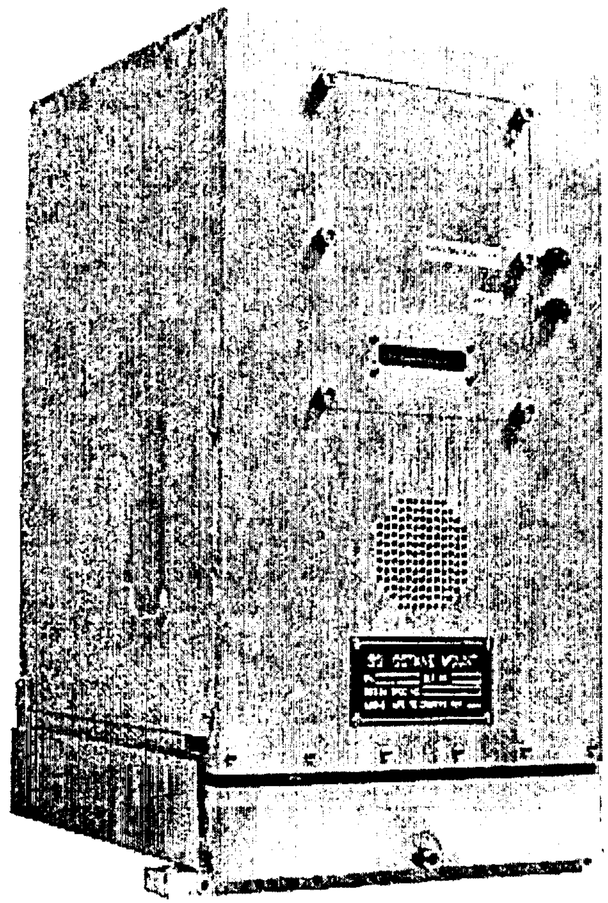
Naval Air Warfare Center
Avionics/Simulation Labs

Defense Micro Electronics Activity
Installation on Larger A/C

Gen Av Airframer
Installation on Smaller A/C

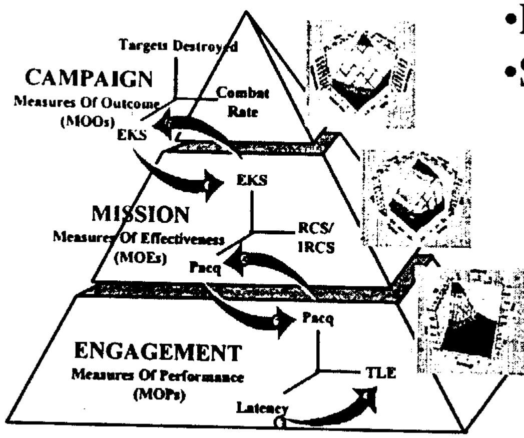
Cambridge Research Associates

Flight-worthy Prototype Hardware



Cambridge Research Associates

Systems Engineering Environment



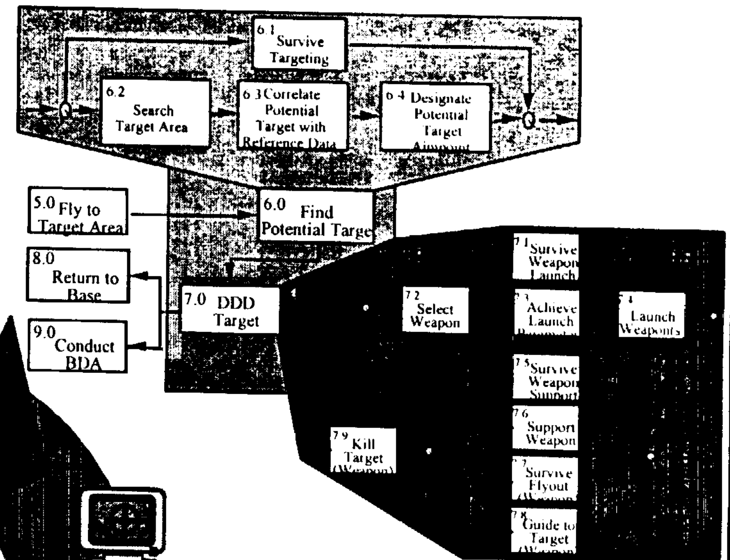
QFD

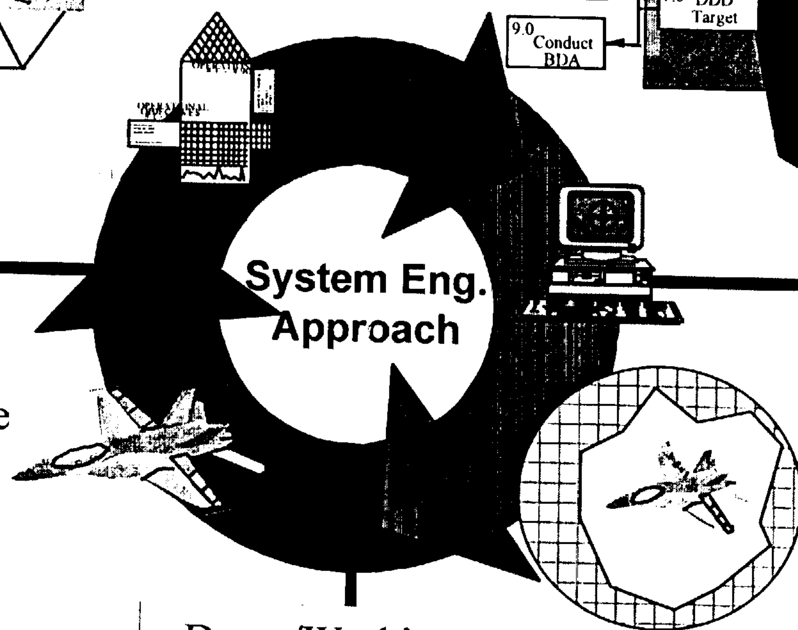
- What is Important?

•Modeling & Simulation Approach
•Structure the Problem

- Complexity
- Confidence
- Resources

Constructive





- Virtual/Constructive Validation
- Debrief
- Test Support
- Capture Tools

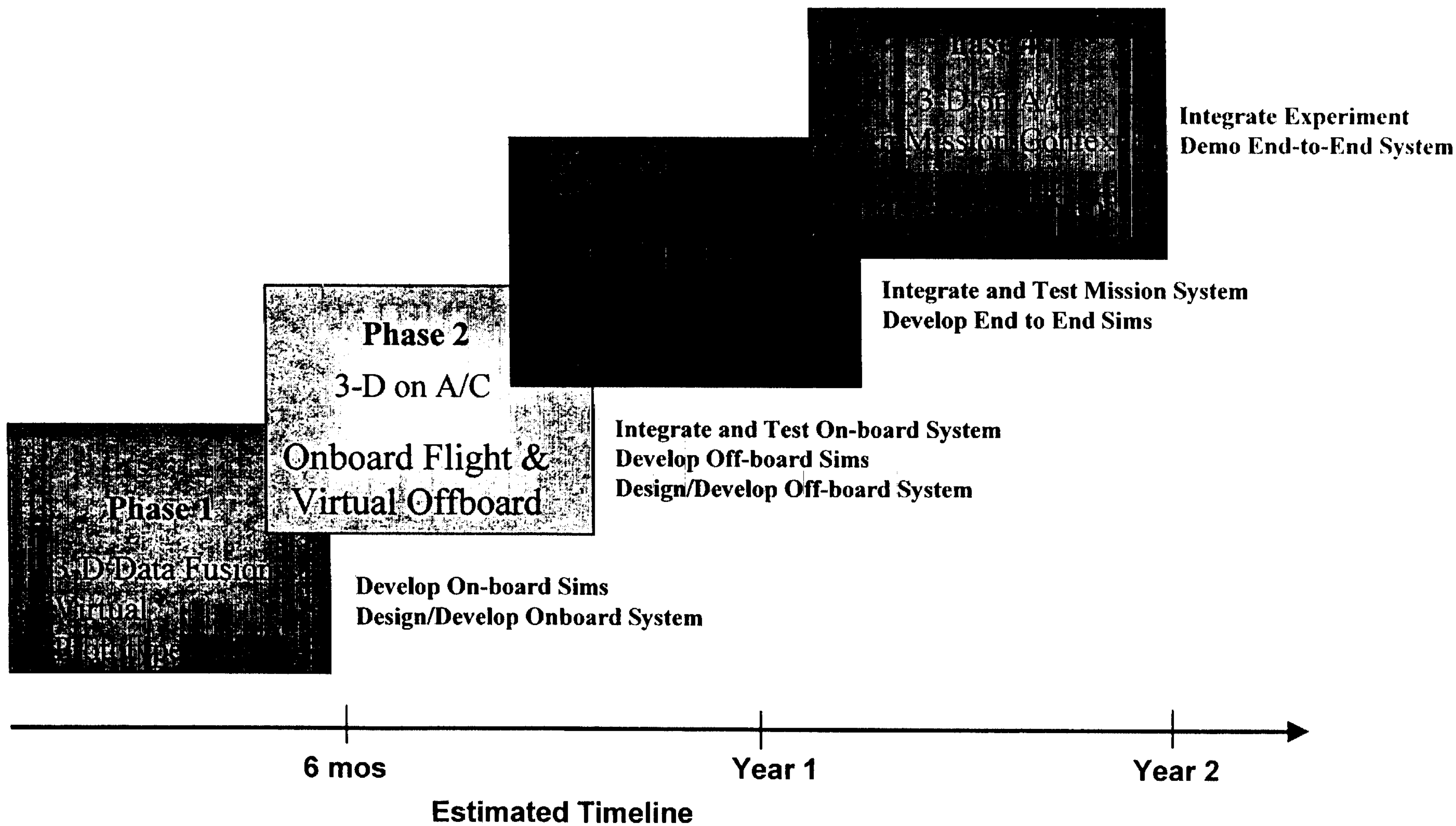
Flight Test & Eval

- Demo/Working Group
- HW/SW In The Loop
- Baseline Testing
- Mod Ops Concept

- Flight Test Risk Mitigation
- Lower Cost
- Lower Fidelity
- Predictive
- Mission Planning

Virtual

Demonstration Steps



Summary

- Defense to civil/commercial opportunity
- Scalable mission planning, execution and debrief capabilities
- Proven team with award winning technologies
- Potential for cooperative funding and asset expoitation

A Quick Overview Of Enhanced Ground Proximity Warning

NASA Synthetic Vision Workshop 2

58-04

Airline Experience With GPWS

- **GPWS Installed on Over 12,500 Jet Aircraft**

  Approx. **100** Not Equipped

- **1975 to 1997**

  125 Million departures in the U.S.&Canada

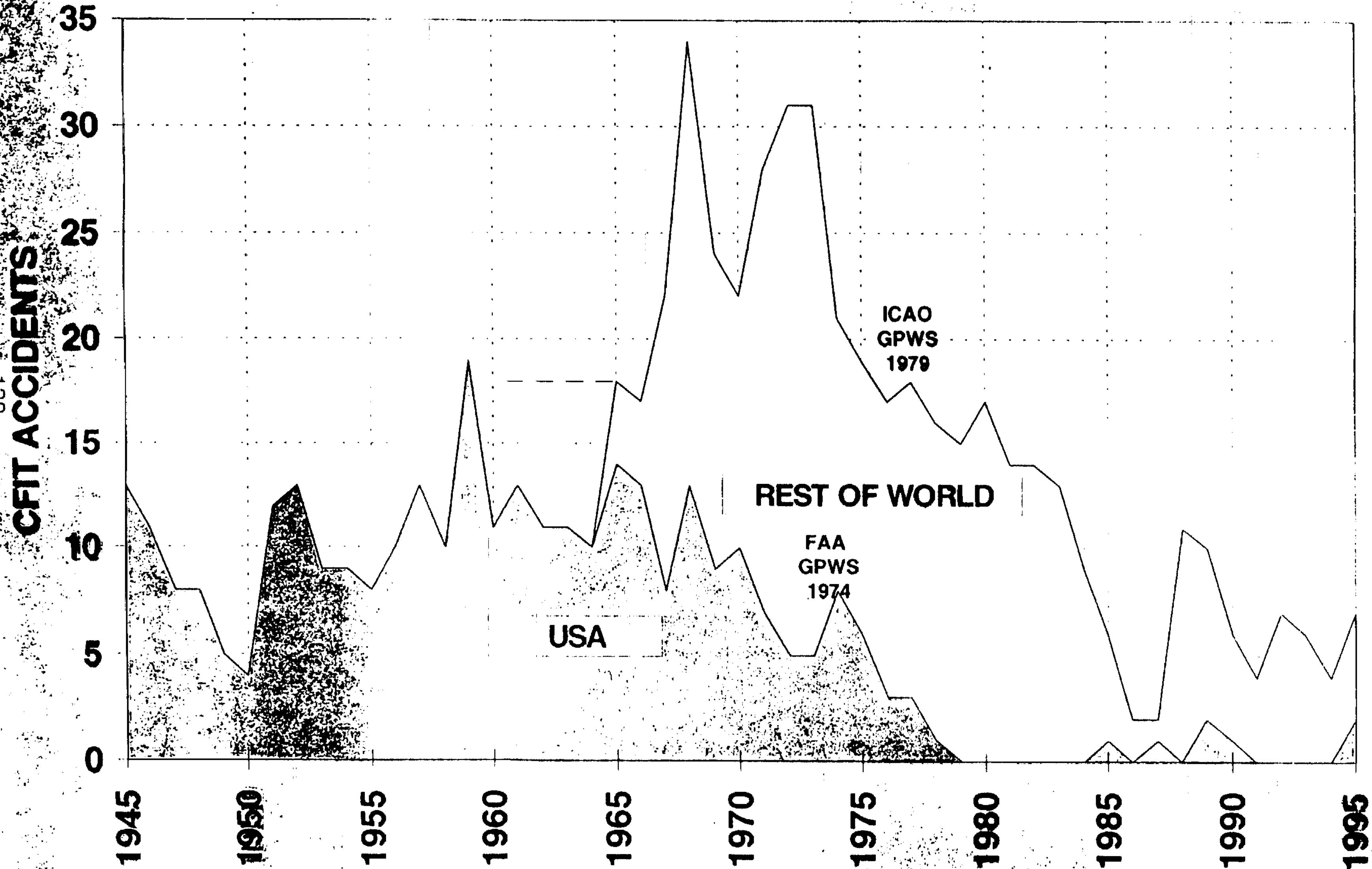
  230 Million departures World Wide

- **U.S. & Canada CFIT Risk**

  Lowered from 0.85 to 0.03 per Million departures or 28 Times

  It Presently Remains at 0.44 for FAR 129 Operations

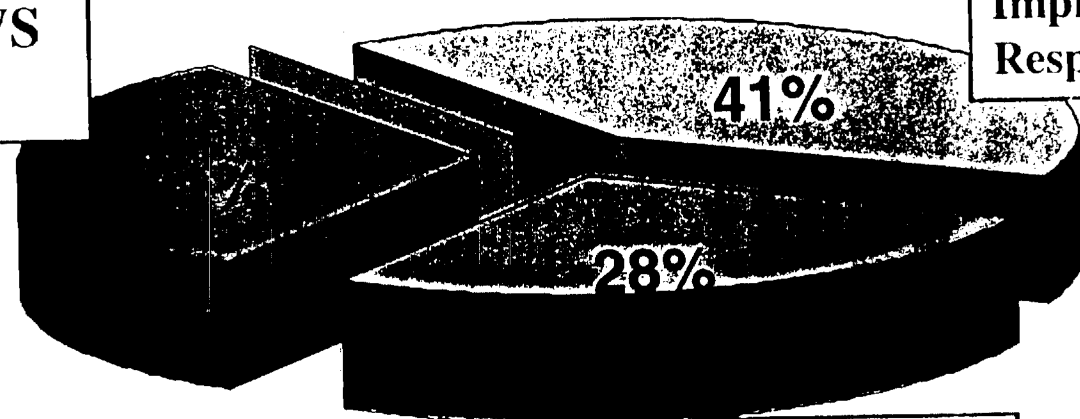
CFIT ACCIDENTS PER YEAR



AlliedSignal Aerospace

COMMERCIAL JET AIRCRAFT ACCIDENTS

1988 - 1995



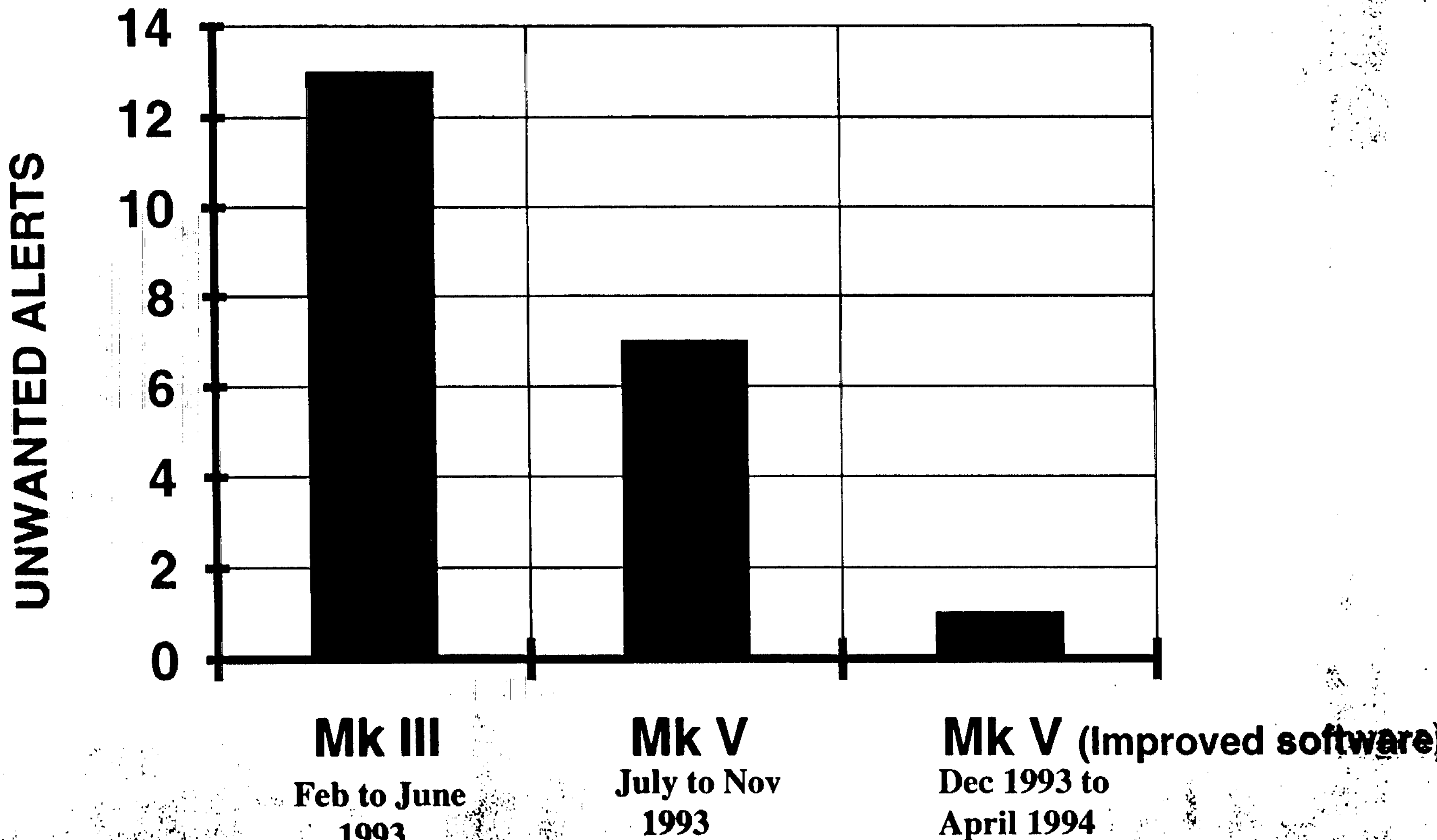
(Aircraft configured to land, hence no warning)

EGPWS Design Requirements were based on addressing GPWS weaknesses while maintaining GPWS safety benefits

AlliedSignal

REDUCTION IN GPWS UNWANTED ALERTS

BRITISH AIRWAYS A320 FLEET



AlliedSignal

EGPWS For Terrain Situational Awareness & Alerting

- Gives Pilot Instant Picture of Significant Terrain Related to Aircraft & Timely Alert before impact ,averaging 50 seconds
- Uses Existing Cockpit Weather Radar and /or EFIS Navigation Displays
- Uses existing Universal GPWS Installations

Flight Path Profile
B737-200
AREQUIPA, PERU
29 FEBRUARY, 1996

CIRCUMSTANCES: While on a non-precision VOR DME approach to runway 09, the aircraft impacted short by 3 NM.

WEATHER: Foggy, drizzle, limiting forward visibility.

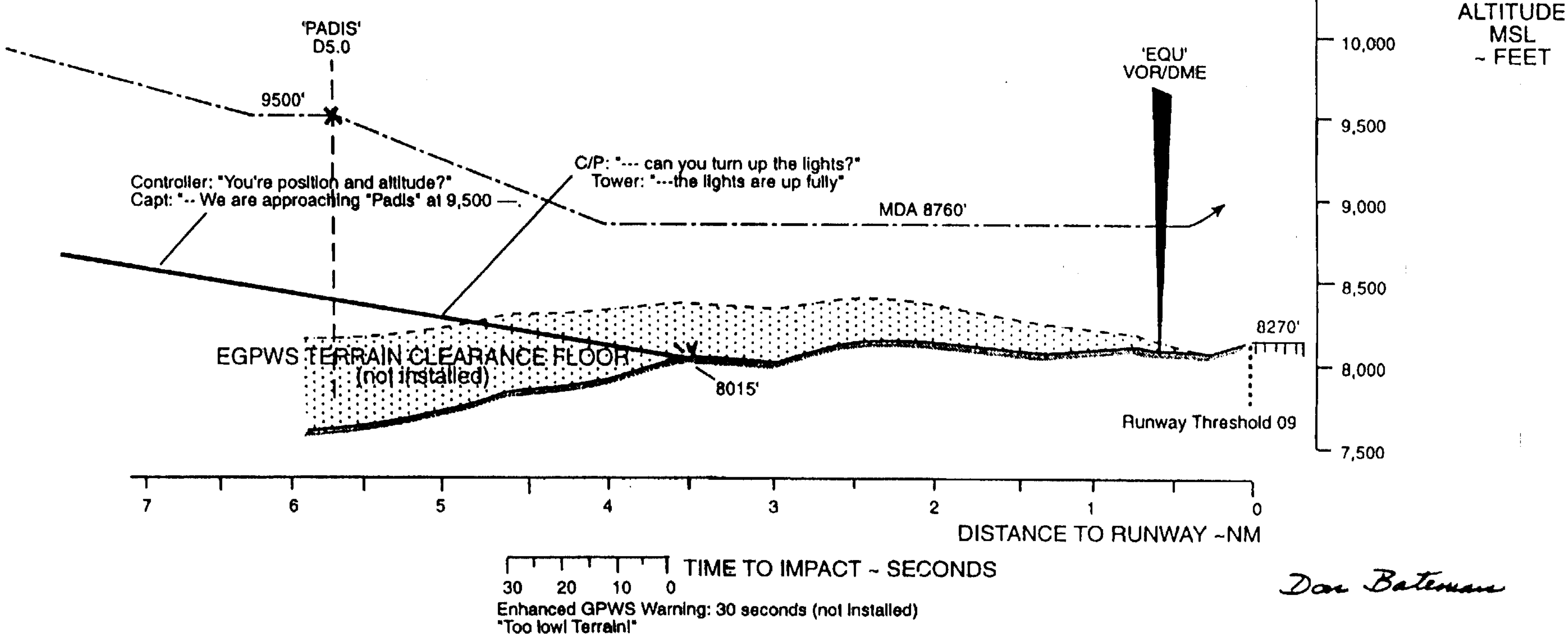
TIME: 20:15 local

CONFIGURATION: Landing

FATALITIES: 123

OTHER: Mark I GPWS (Collins) installed. No apparent warning. The pilots may have seen the runway lights initially, but lost them as they descended into foggy conditions.

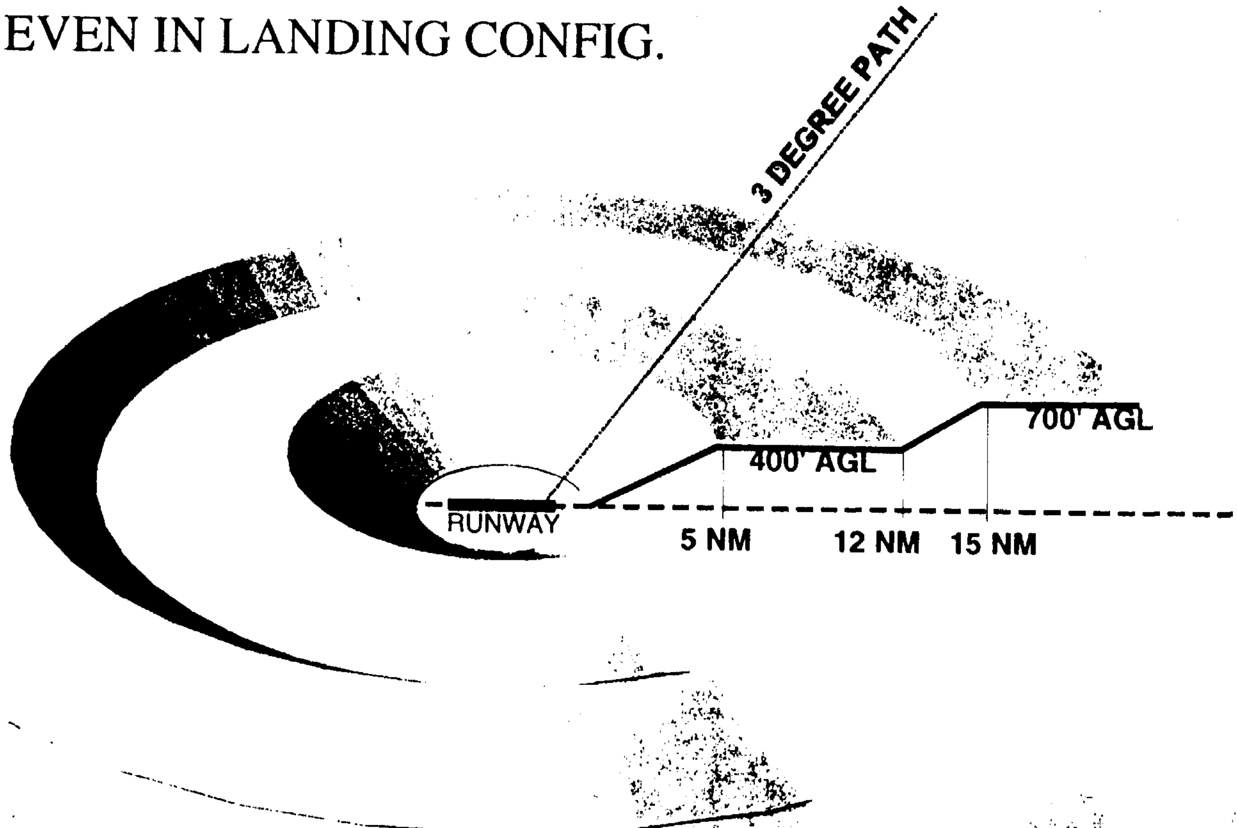
An Altimeter error or deliberate effort to get down early?



Don Bateman

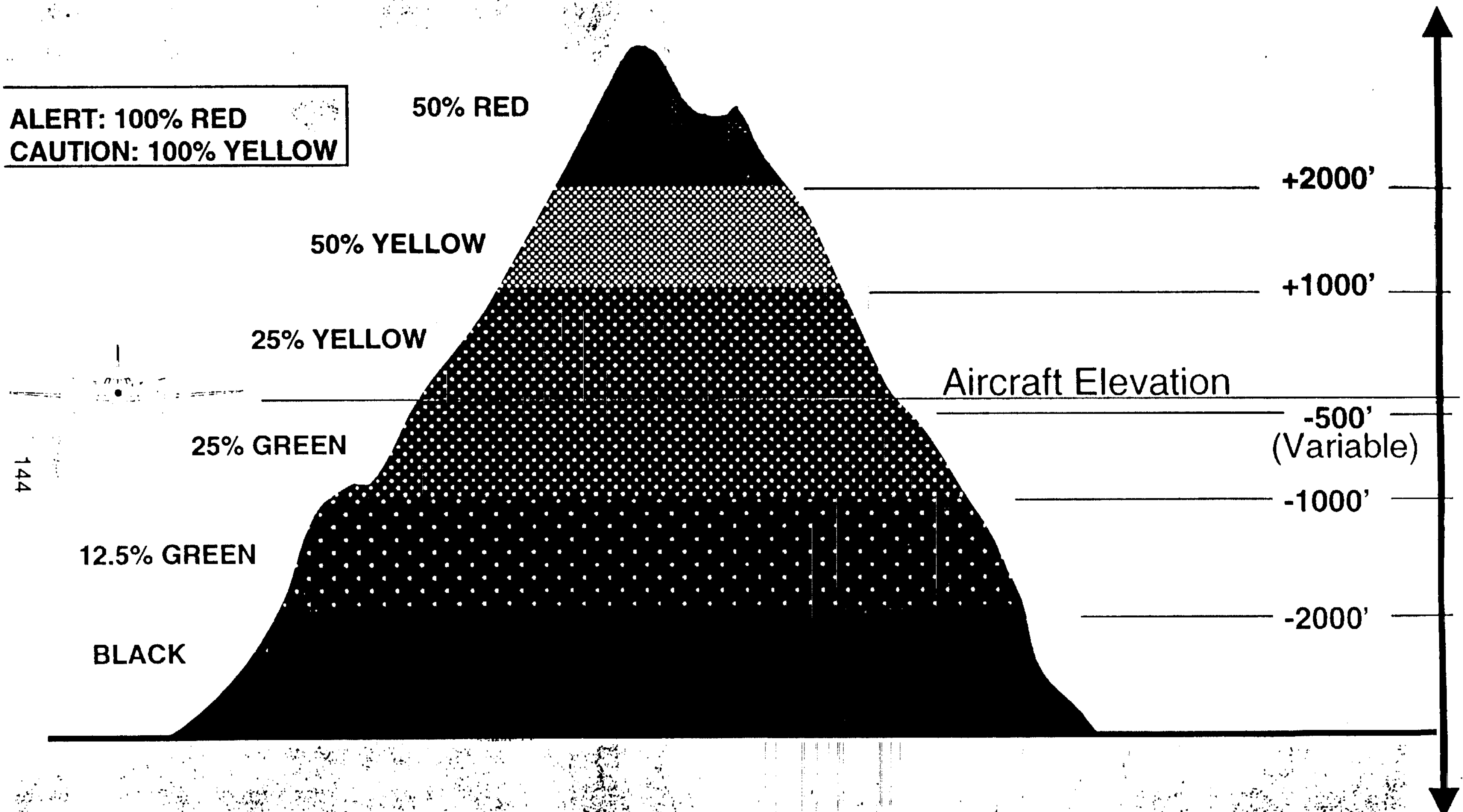
TERRAIN CLEARANCE FLOOR

- AIRCRAFT POSITION / HEADING VS.
- AIRPORT LOCATION DATABASE, TO GIVE
- PROTECTION EVEN IN LANDING CONFIG.

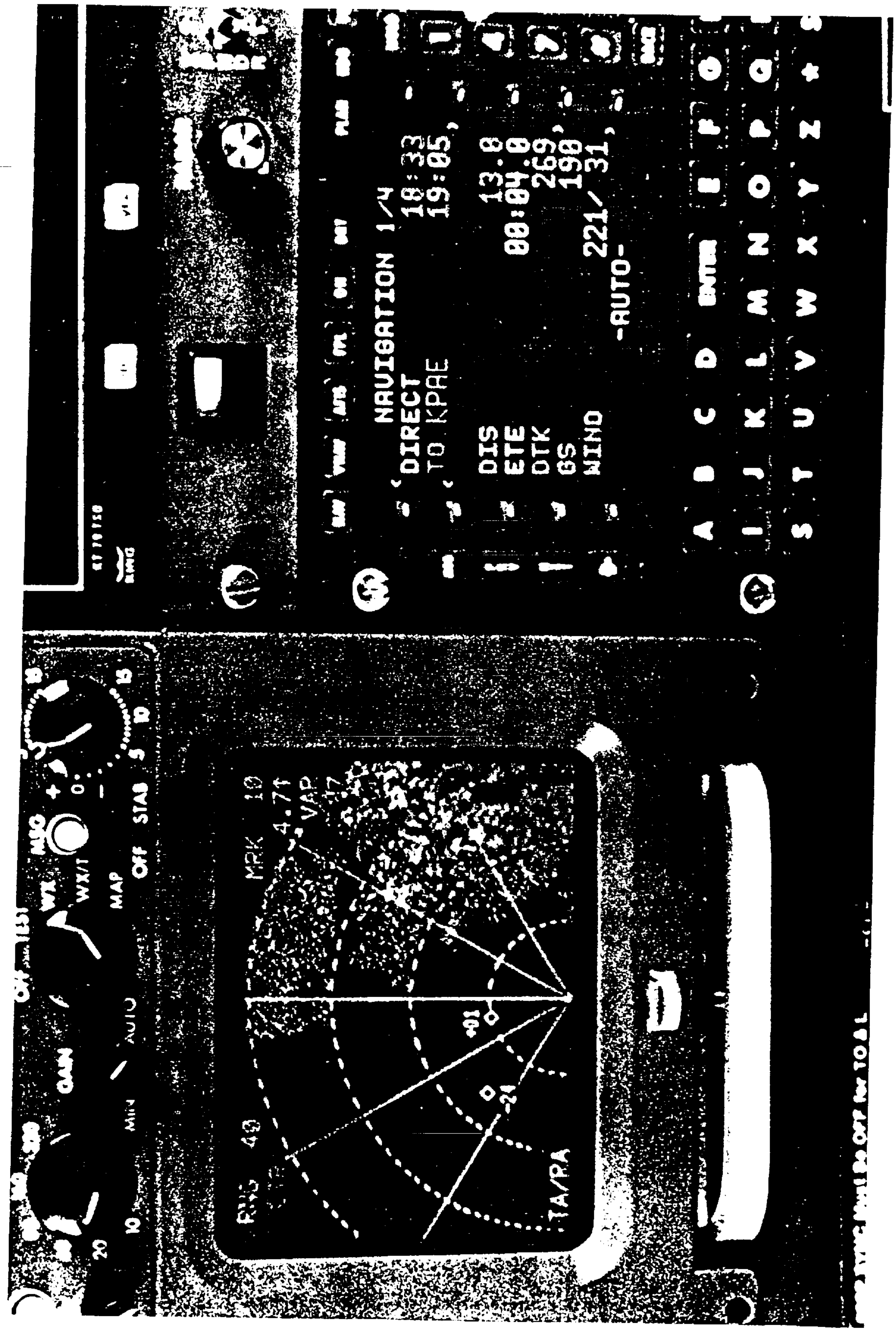


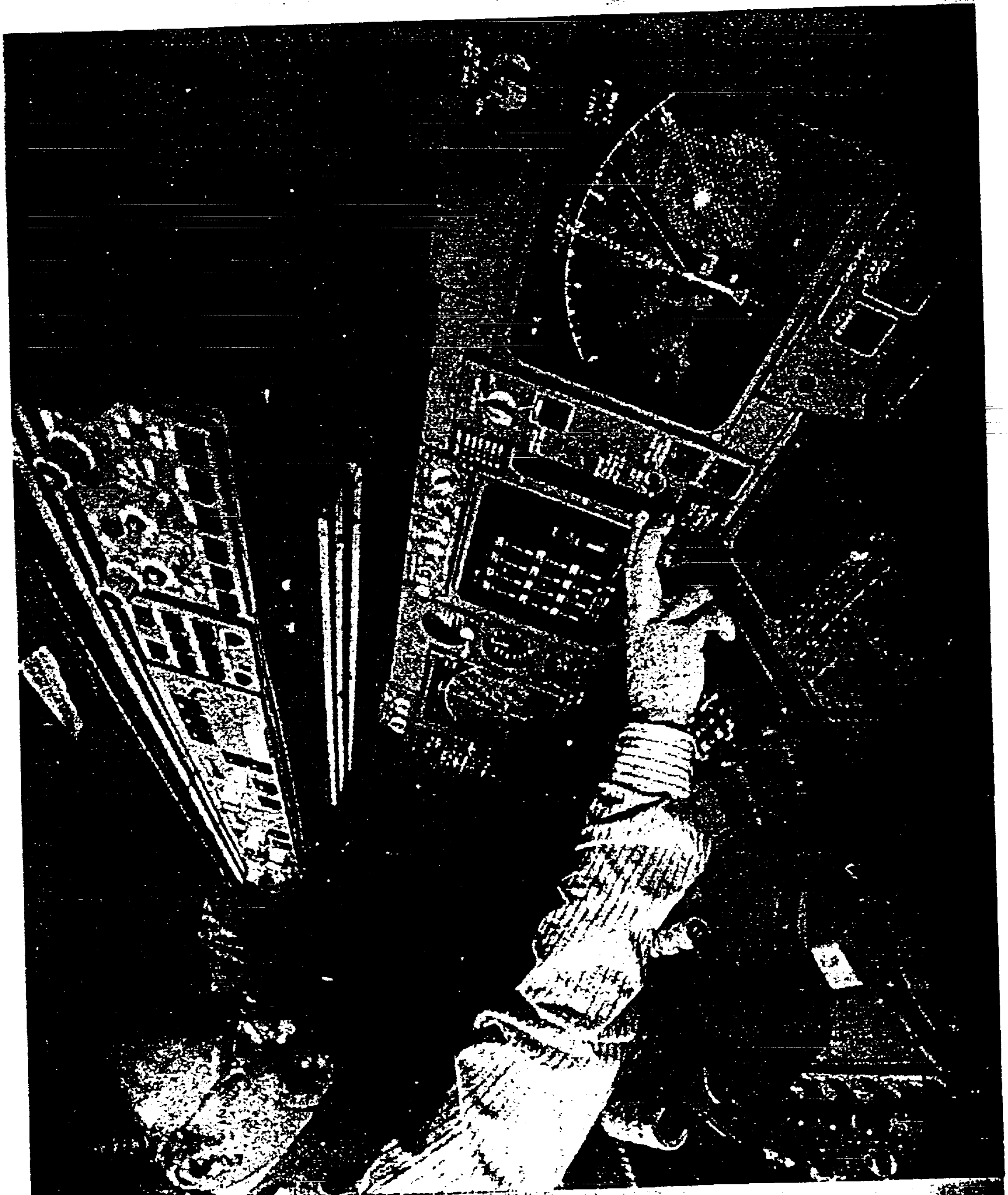
AlliedSignal Aerospace

EGPWS DISPLAY COLOR CODING
(SIMPLIFIED)

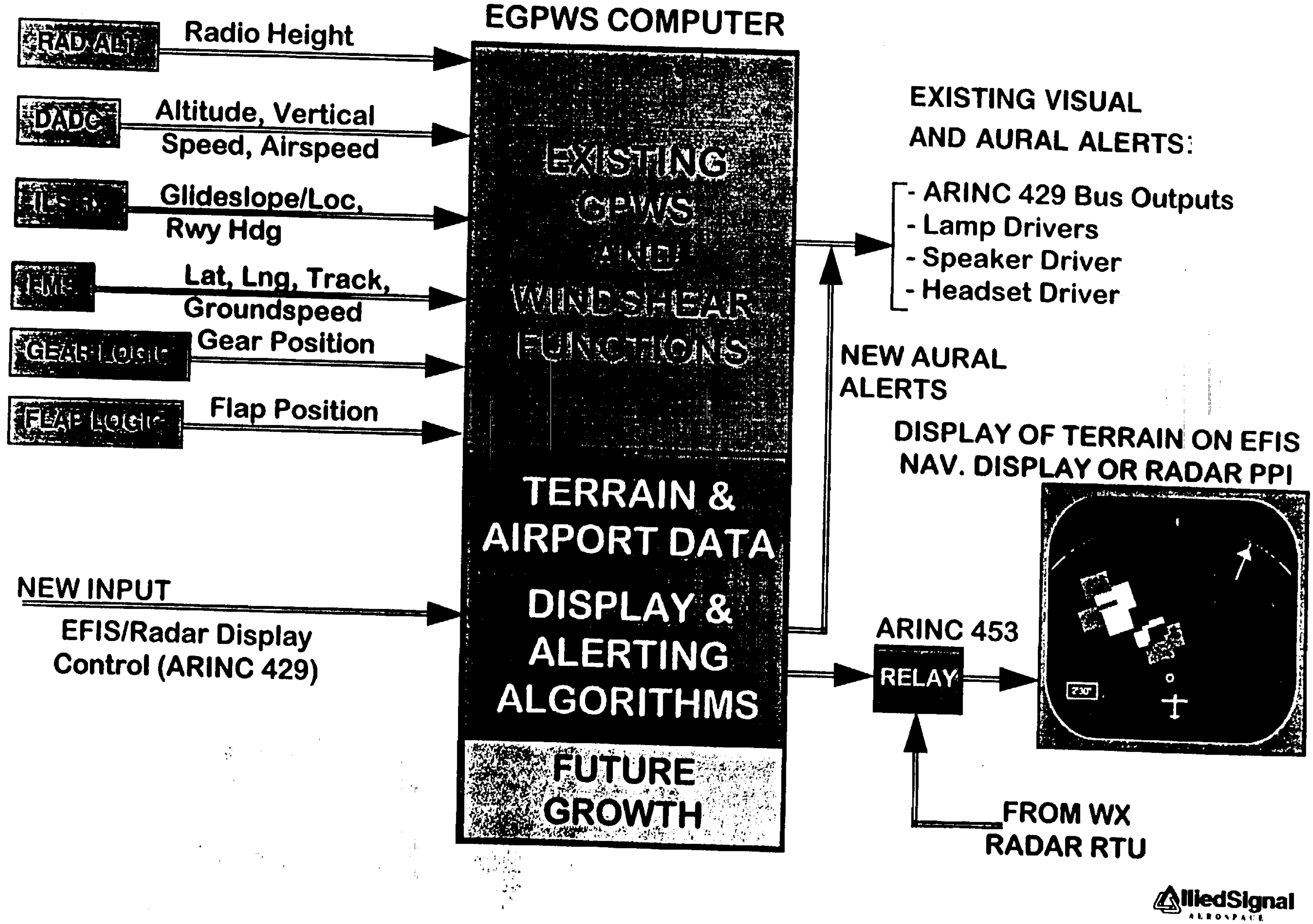


AlliedSignal AEROSPACE


NAVIGATION 1/4
DIRECT 18:33
TO KPAE 19:05
DIS 13.8
ETE 00:04.0
DTK 269
GS 190
WIND 221/ 31
-AUTO-
TA/PA
MRK 10
VAP
OFF
STAB
MAP
WX/T
AUTO
GAIN



EGPWS SYSTEM



ENHANCED GPWS

- SAME FORM FACTOR AS EXISTING GPWS.
- UTILIZES EXISTING PROVISIONS
- EXISTING GPWS FUNCTIONS MAINTAINED/IMPROVED
- DATABASE: PCMCIA ACCESSABLE

AlliedSign

EGPWS PAY BACK

- *With EGPWS installed,we should be able to eliminate the Loss of One Aircraft per Year Operating Under Part 121 and 129 inside the USA, or to/from the USA ,and the Lives of Passengers and Crew of that Aircraft*
- *Plus Another Two Aircraft Losses and Lives World Wide can be Averted*

Terrain Data Bases

- Inherently Imperfect But Useful For Non-Critical Applications
- Integrity Level Not Sufficient For Useage In Critical Systems
- Critical Systems Require Independent Real Time Validation

Display Of Terrain In The Cockpit

- Existing EGPWS Displays Are Adequate, Useful, Practical, But Have Limitations
- Improvements Are Desired, ie. 3 D
- NASA Contributions Are Necessary And Recommended To Address The Human Factor Issues For Future Displays

CFIT-- A Five Year Report Card

Results Of 1992 ICAO,Flight Safety Foundation, Industry Task Force's Five Year Program To Reduce Controlled Flight Into Terrain (CFIT)Accidents

NASA Synthetic Vision Workshop2

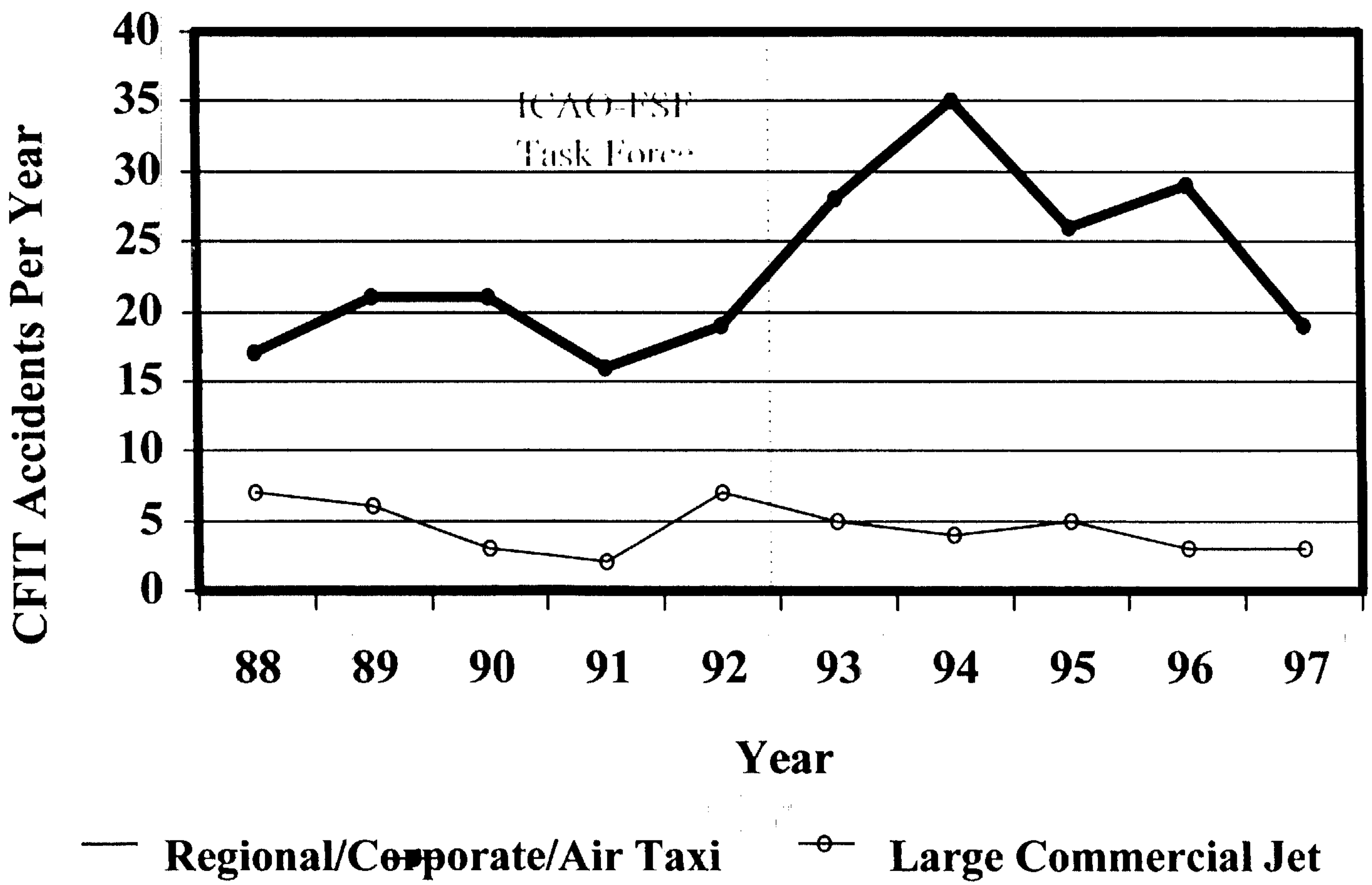
January 28, 1998

Don Bateman AlliedSignal Redmond Wa.

1992 CFIT Task Force Five Year Objectives

- Cut CFIT Risk Factor In One Half By 1997
- Not More Than a Factor of Two Difference in CFIT Risk Factor Between the Lowest to the Highest Risk Geographical Areas of the World

World Civil Turbine Powered CFIT Accidents



1997 Five Year Results

- **Corporate Jet Aircraft CFIT Risk Reduced By Approximately 60%**
- **Airline Jet Aircraft CFIT Risk Reduced By 37%**
- **Regional-Business-Air Taxi CFIT Risk Beginning to Fall**
- **Maximum Difference in Geographical CFIT Risk Factor has Dropped From 80 to 40**

Task Force's Efforts With The Greatest Returns

- Publicizing The CFIT Risk and the 'Traps'
- Airline and Corporate Awareness
- Pilot Awareness, Recurring Training, Recovery Procedures, Videos
- Dissemination of Training Materials
- GPWS Fitment
- The Addition of Colored Topographic Terrain to Instrument Procedures.

Task Force's Disappointments

- Failure to Disseminate CFIT Training and Video Material to Regional Air Carriers and Air Taxi Operators. (Lack of Money and Translations)
- Failure to Interest Regional Operators in Installing Radio Altimeters and GPWS
- Failure to Interest World States to Add Minimum Safe Alitude Warning Software & Procedures To Existing Air Traffic Control Equipment

Disappointments (Cont'd)

- Failure to Interest States to Standardize, or Put a Lower Limit on the Minimum Approach Slope, such as Two Degrees for Non Precision Approaches

Hull Loss Accident Rates

- **World Wide**

  1983 to 1992................1.46 per Million departures

  1993 to 1997................1.38 per Million departures

  Improvement Over 10 Years of **5.5%**

- **U.S.& Canada**

  1983 to 1992................0.55 per Million departures

  1993 to 1997................0.47 per Million departures

  Improvement Over 10 Years of **14%**

CFIT Hull Accident Losses

- **World Wide**

  1983 to 1992............0.35 per Million departures

  1993 to 1997............0.23 per Million departures

  Improvement Over 10 Years of **37%**

- **U.S.& Canada**

  1983 to 1992.............0.03 per Million departures

  1993 to 1997.............0.03 per Million departures

  No Improvement

The Future

- CFIT Awareness and Training Has Helped But May Be Transitory
- GPWS Technology Has Demonstrated a CFIT Risk Reduction of 30, But GPWS Has Reached its Limitations
- EGPWS Technology Will Further Reduce The CFIT Risk By Another Factor of 10
- Future Technology Has Great Promise

Terrain Clearance Systems... What's Next?

SINGLE SCAN S9-03

Panel Members

- Mike Norman, Ph.D.
  - Advanced Programs R&D Project Test Pilot, Boeing Long Beach
- Don Bateman
  - Chief Engineer, Flight Safety Systems, Allied Signal
- Paul Leckman
  - Senior Research Pilot, Boeing Seattle
- Bill Langdon
  - Line Pilot, United Airlines
- Charley Wood
  - Project Pilot, Production Flight Test, Boeing Long Beach

Non-Attribution

Employees of companies and government agencies involved in the Aviation Industry have been invited to participate in this workshop, to foster a frank and open interchange between Government and Industry, concerning matters relevant to long term improvements in aviation safety. The statements and opinions expressed by audience and panel members in this discussion are their own, based on experience they have gained. Positions stated explicitly or inferred do not represent the positions of their respective companies or organizations, unless stated otherwise. Workshop participants are requested not to attribute these statements and opinions in any other context.

Purpose

- Description of an existing Terrain Clearance 2-D system.
- Discussion of experience gained with that system.
- Potential future improvements
- Encourage audience discussion of issues and areas of concern
- Output - minutes/lists to be used in preparation of NASA Research Announcement

Some Personal Thoughts...

- Pilots are sometimes workload and information saturated in the current environment
- More information doesn't necessarily mean more safety
- Pilots manage information and safety buffers through personal and institutionalized strategies. Designers must address (and assist) those strategies in future systems
- Don't allow pilot to become the sole cockpit integrator of critical information

Some Personal Thoughts (Continued)...

- Provide tactical (what to do) AND strategic (why to do it) information in balanced amounts
- Don't apply technology just because we can
- Requirements Driven Approach will achieve best pilot and organizational buy-in

Itinerary

- Don Bateman - Enhanced Ground Proximity Warning System Description
- Paul Leckman - Flight Test Experience with EGPWS
- Charley Wood - Stand Alone Terrain Conflict Detection
- Bill Langdon - Follow-on Systems Issues and Areas of Concern
- Panel/Audience Discussion
- Minutes/Proceedings (NASA)

Program Challenge

- Think of the last 10 fatal aviation accidents
- Now, think of what it would have taken to prevent (with complete assurance before hand) 9 of them, through design, procedural, or institutional changes
- This is the challenge at hand

Daimler-Benz Aerospace
Airbus

Control / Display Unit (Touch Screen Device) for Inflight Route Planning and Flight Plan Execution

K. Dieter Kricke

Claudia Lessel

NASA Synthetic Vision Workshop Two

Hampton, Virginia, January 27 – 29, 1998

SINGLE SCAN

5,0-03

Daimler-Benz Aerospace
Airbus

Dr.-Ing.
K. Dieter Kricke

Head of
System Technology
Cockpit and Avionics

Daimler-Benz Aerospace Airbus GmbH
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D-21129 Hamburg
P.O.Box 95 01 09
D-21111 Hamburg
Phone (0 40) 74 37-38 87
Telefax (0 40) 74 37 37 98
Telex 2 1 950-0 da d

e-mail : claudia.Lessel@airbus.dasa.de

Control/Display Unit (Touch Screen Device) for Inflight Route Planning and Flight Plan Execution

In the context of an experimental technology study a demonstrator version of a control/ display unit, called Touch Screen Device, was developed at DASA Airbus in Hamburg, which permits an inflight (low altitude) route planning and flight plan execution for a future military transport aircraft.

Figure 1 shows the Touch Screen Device as part of a control station for the Tactical Operator installed in our engineering flight simulator.
The Touch Screen Device consists of a colour LCD (Liquid Crystal Display) and a touch-sensitive overlay. The display formats consist of a graphical part and a menu column at the right edge. There are two basic operational modes:

- Navigation Mode
- Planning Mode.

In the Navigation Mode the display formats are consistent with those of an (AIRBUS) Navigation Display. The basic graphical information displayed is:

- Present Position
- (Active) Flight Plan.

Additionally, ranges can be changed, the orientation of the display can be modified (ARC, ROSE, PLAN mode), navigational aids (VOR, TACAN, NDB ground stations and airports) can be selected, and alternative flight plans can be displayed.

On the basis of DLMS (Digital Land Mass System) data additional map information can be presented as for example:

- Topography and the vertical flight profile (Figure 2)
- Perspective view of the terrain and the flight progress (Figure 3)
- Terrain elevation and obstructions relative to present aircraft height (Figure 4)
- Military threats or other airspace restrictions (Figure 5).

The Planning Mode permits to generate a (low-altitude) flight profile either manually or automatically. In the manual mode the horizontal flight route has to be defined, first, for instance, by manual-interactive input of waypoints. Then, the vertical profile is calculated automatically on the basis of DLMS data taking into account terrain and obstructions as well as the performance of the aircraft.

The trajectory from the present position to a given destination waypoint can also be generated completely automatically.

Figure 1: Control/Display Unit (Touch Screen Device) for Inflight Route Planning and Flight Plan Execution

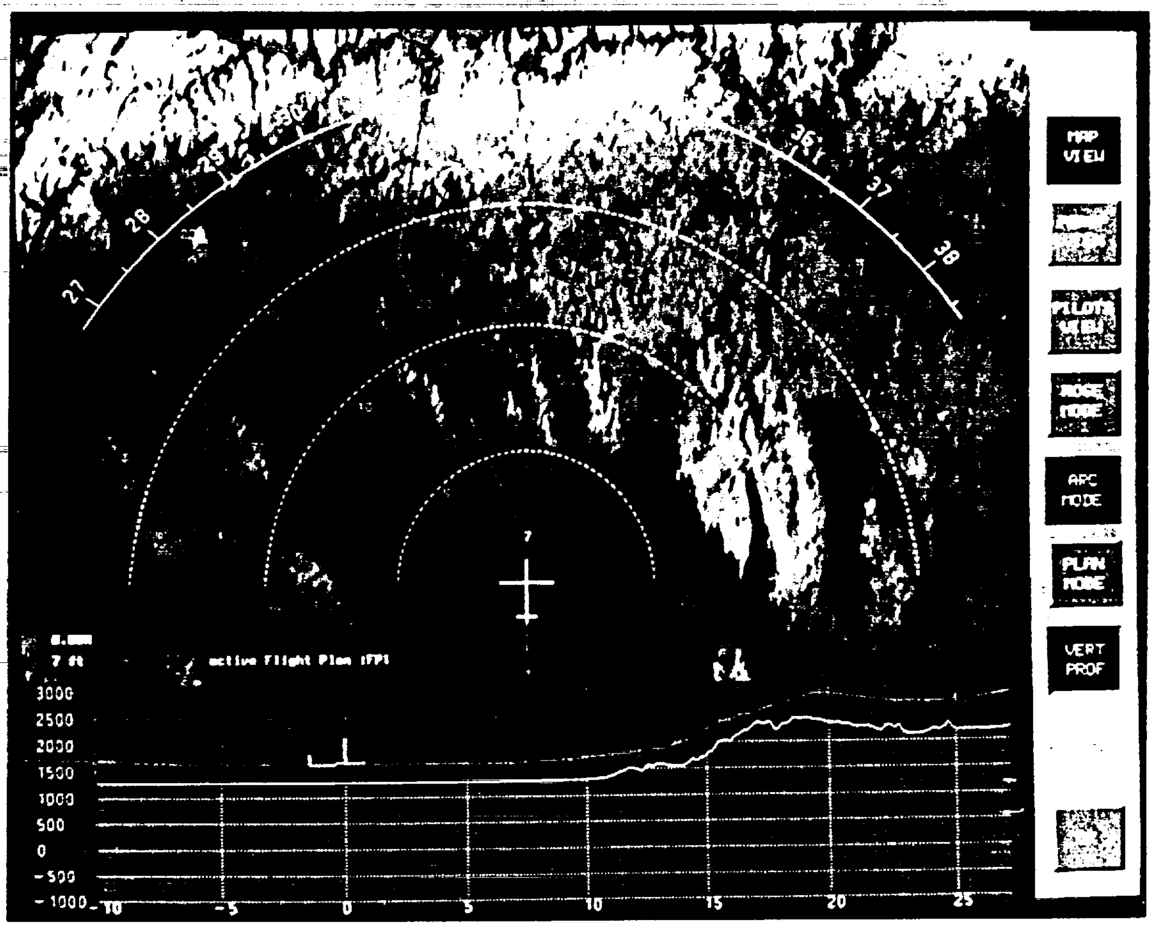


Figure 2: Navigation Display Format: Topography and Vertical Flight Profile

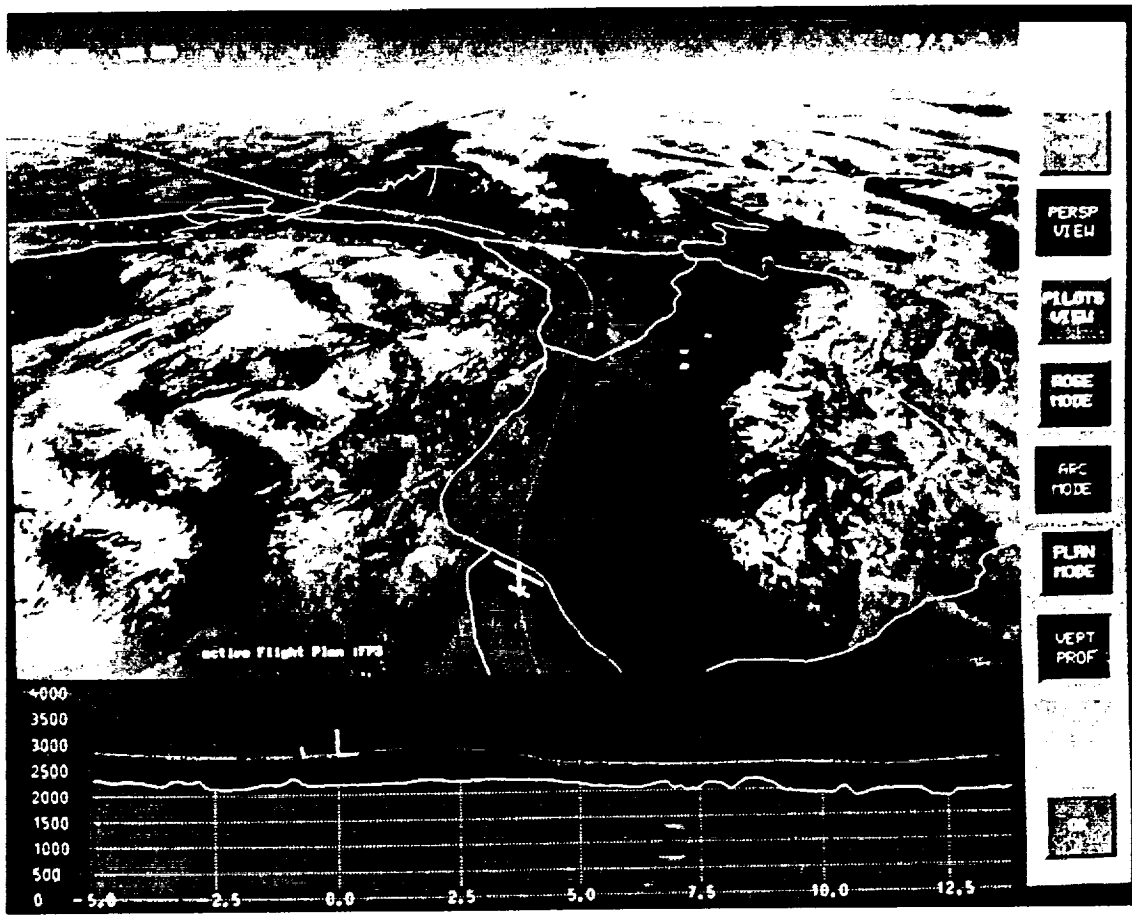


Figure 3: Navigation Display Format:
Perspective View of Terrain and Flight Progress

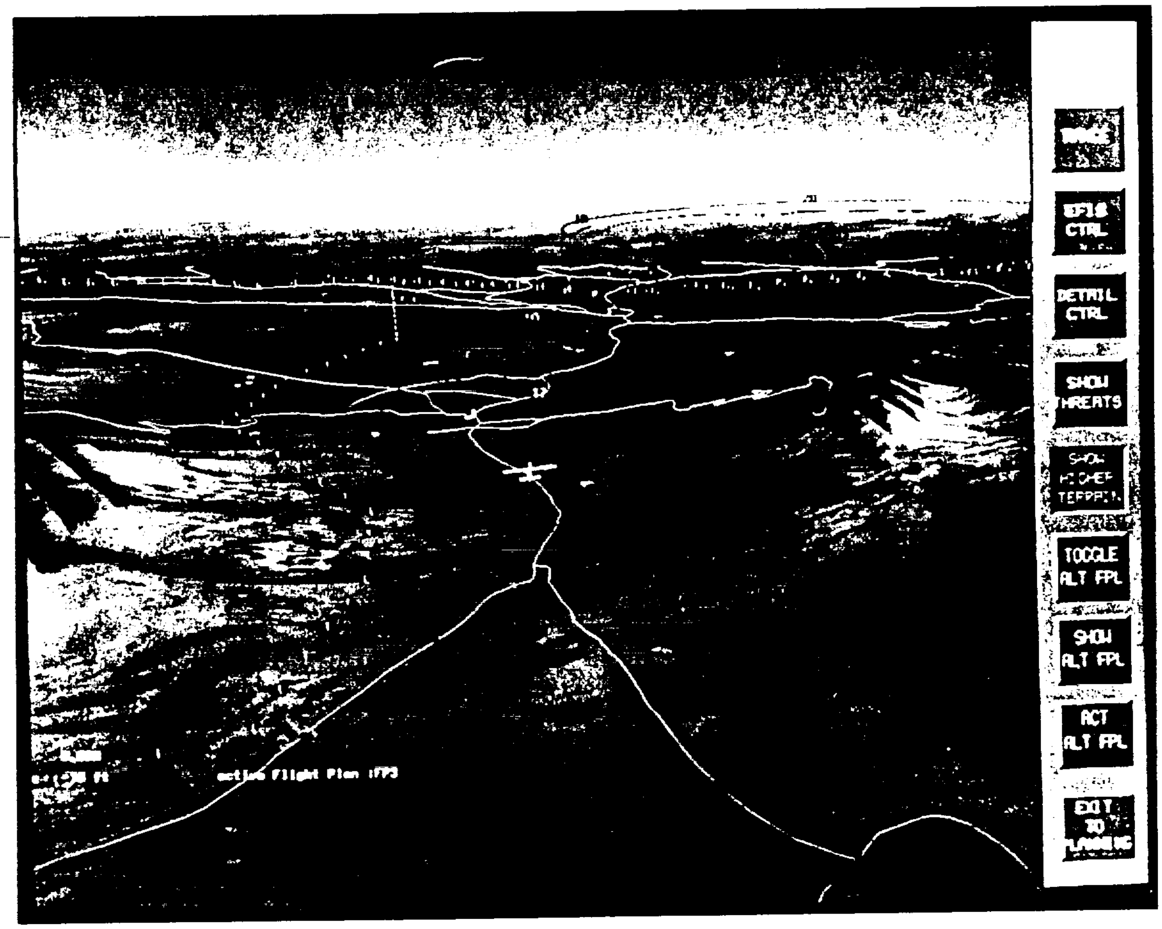


Figure 4: Navigation Display Format:
Terrain Elevation and Obstructions
Relative to Present Aircraft Height

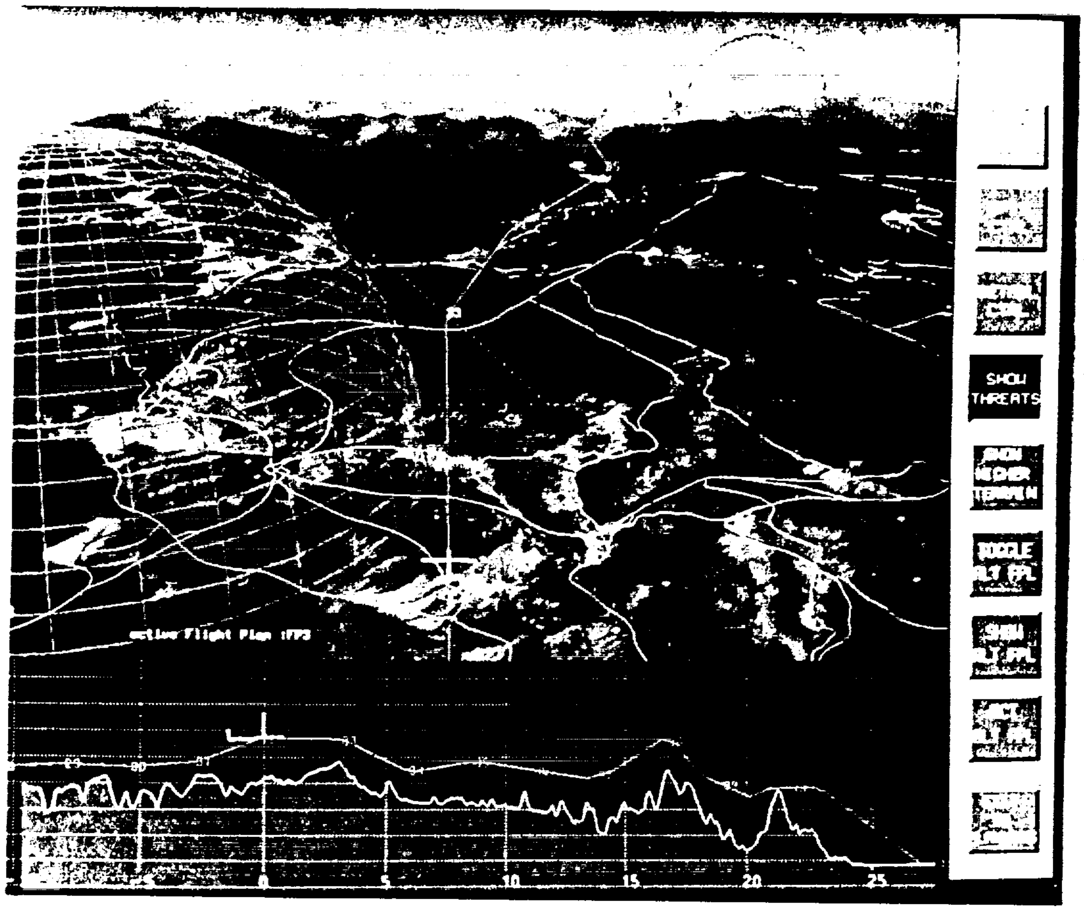
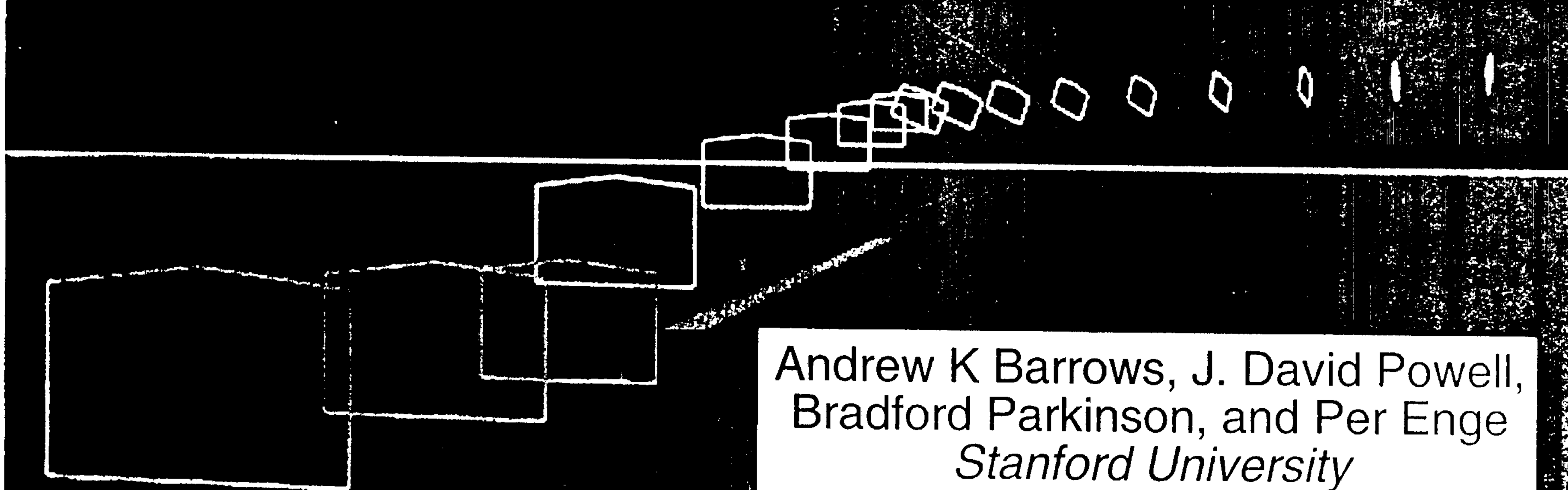


Figure 5: Navigation Display Format:
Military Threats of other Airspace Restrictions

519-03

Tunnel-in-the-Sky Display and Sensor Work at Stanford University



Andrew K Barrows, J. David Powell, Bradford Parkinson, and Per Enge
Stanford University

NASA Synthetic Vision Workshop
NASA Langley Research Center
27 January 1998

Tunnel Display Project

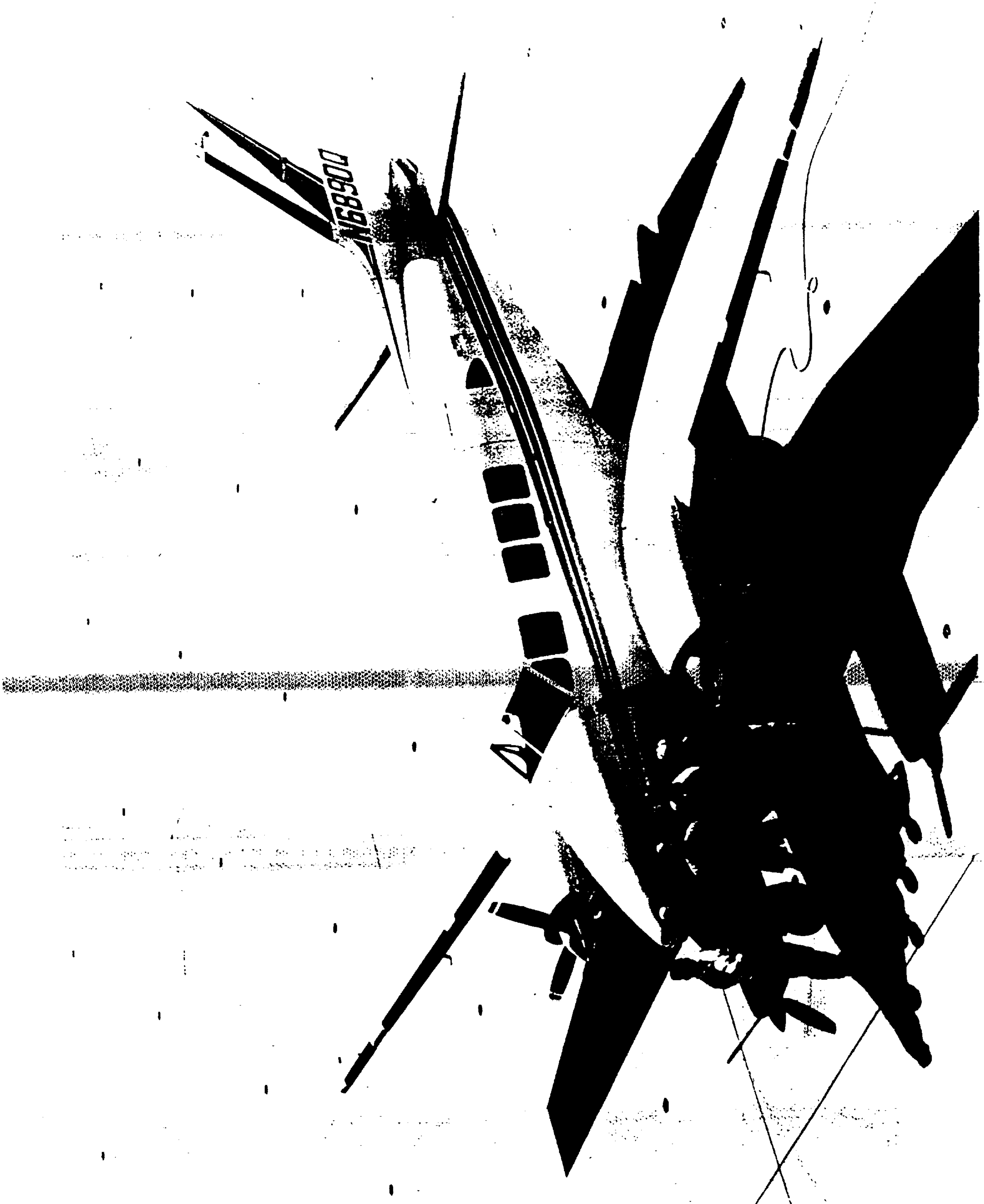
Goal: Use GPS position and attitude data to make flying an aircraft safer and easier

- A 50-year-old idea:
  synthesized picture of outside world
- Simplified operation and enhanced accuracy
- Improved situational awareness
  ("warm fuzzy feeling")
- Enabling technologies offer reduced cost for access by all sectors of aviation
- Most previous work has focused on simulation
- Address operational issues through flight testing

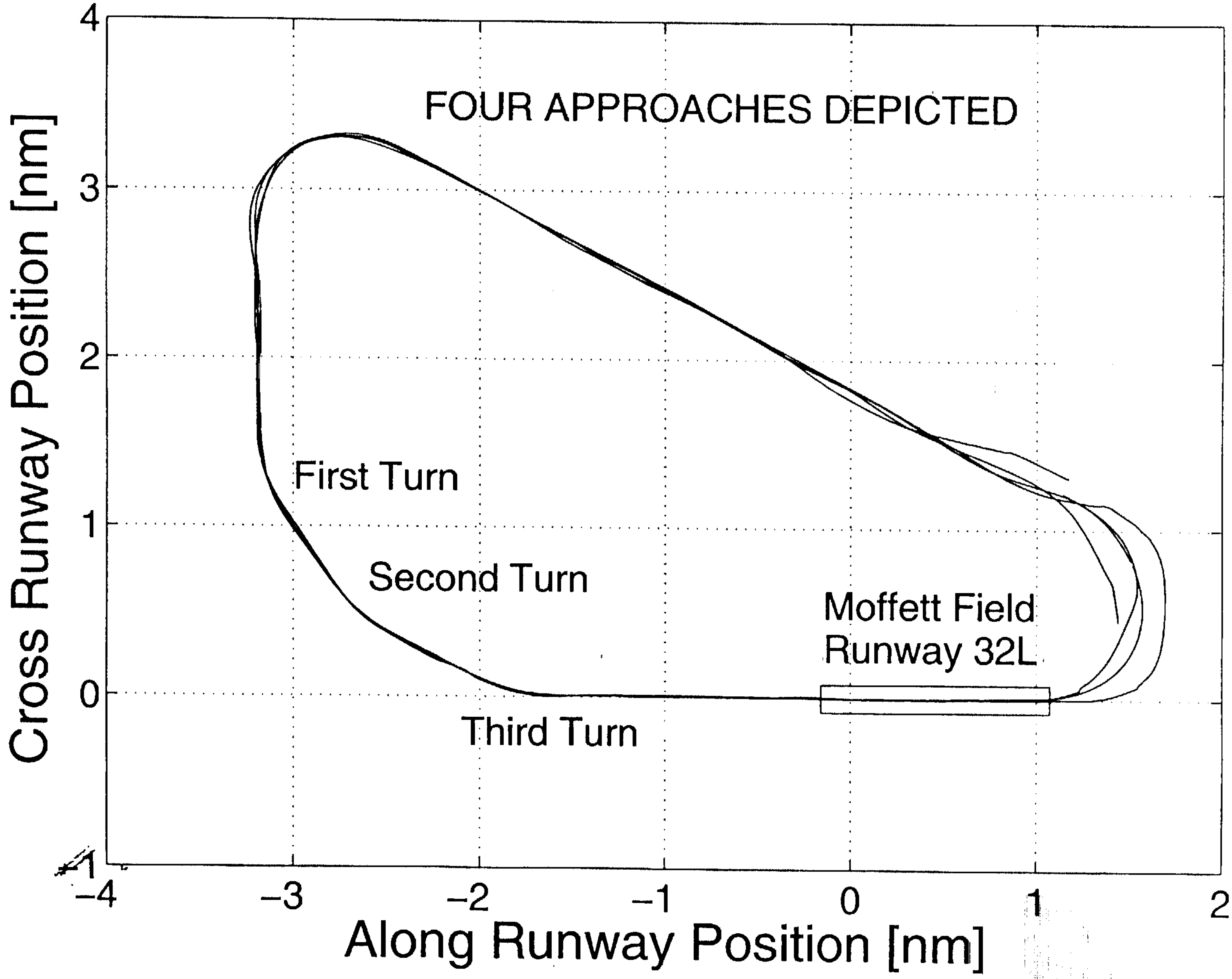
Sensor Issues

NEGLECTED PART OF PROBLEM

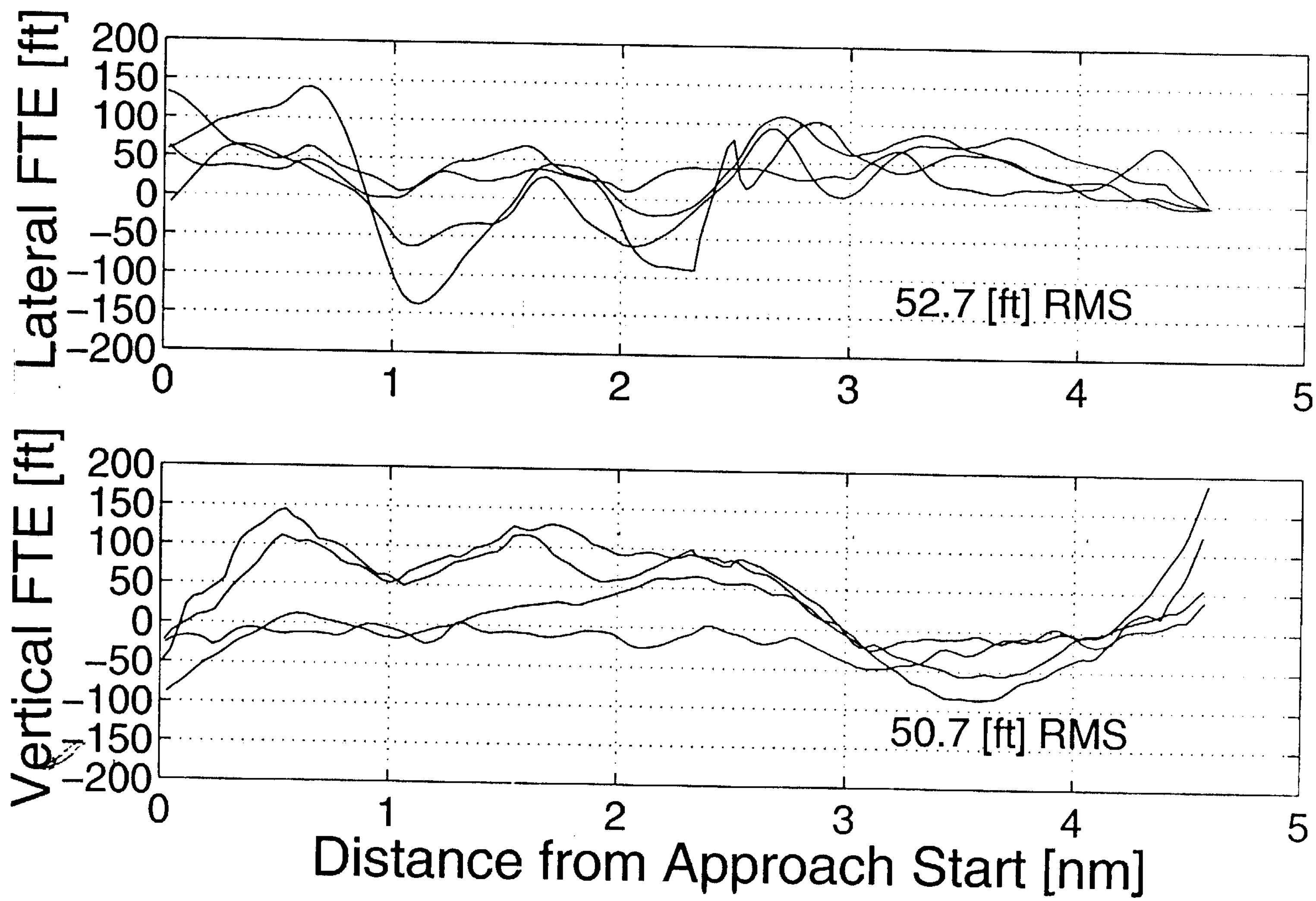
- High bandwidths needed
  - Innermost loop of flight control
  - Pilots will not tolerate "lags" or "jerkiness"
- Greater level of integration needed
  - Especially for light aircraft
- Non-air-carrier aircraft need inexpensive sensors
  - Differential GPS for positioning
  - Expensive INS or AHRS replaced by GPS attitude and automotive IMU

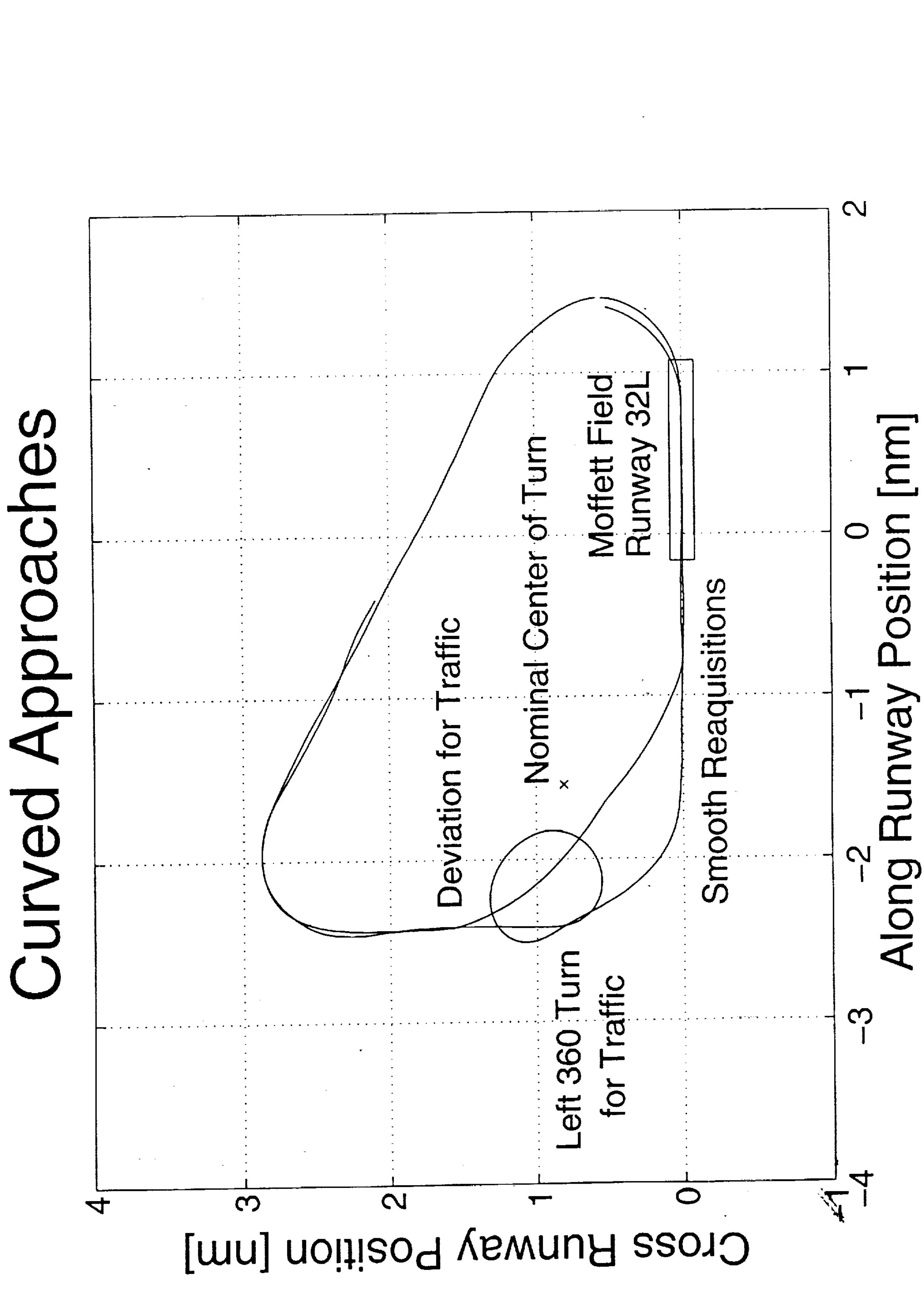

N6890D

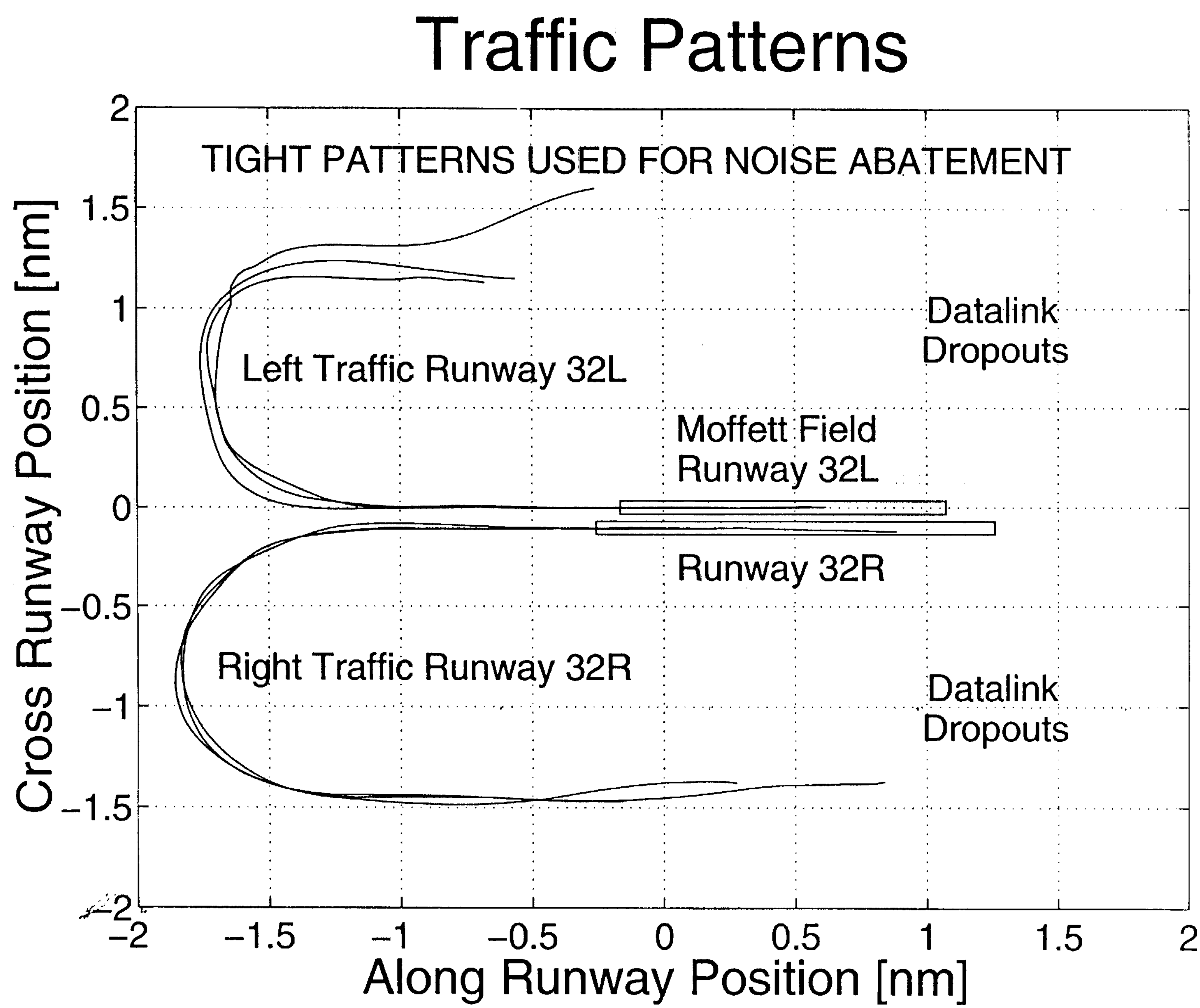
Segmented Approaches

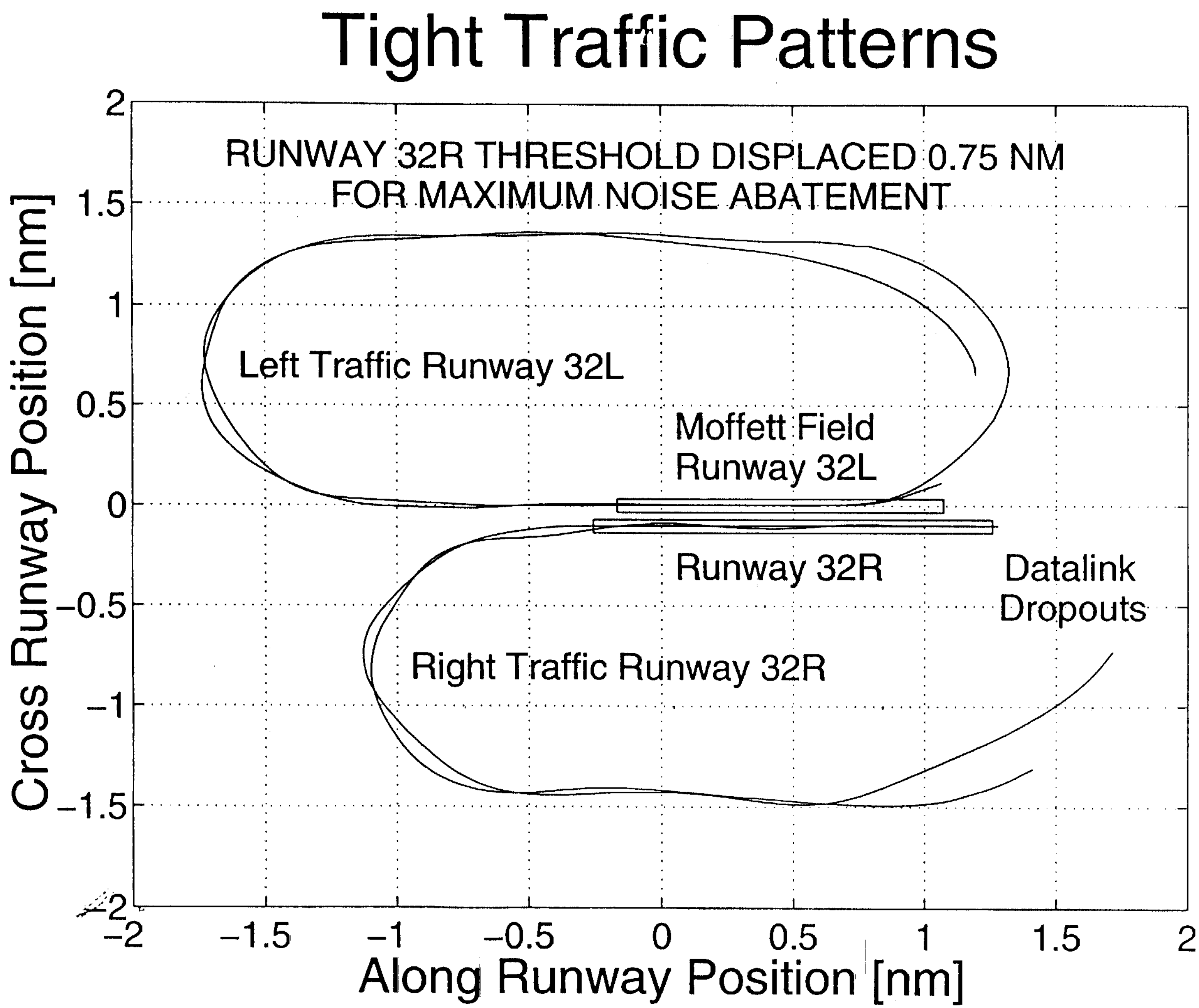


FTE on Segmented Approaches

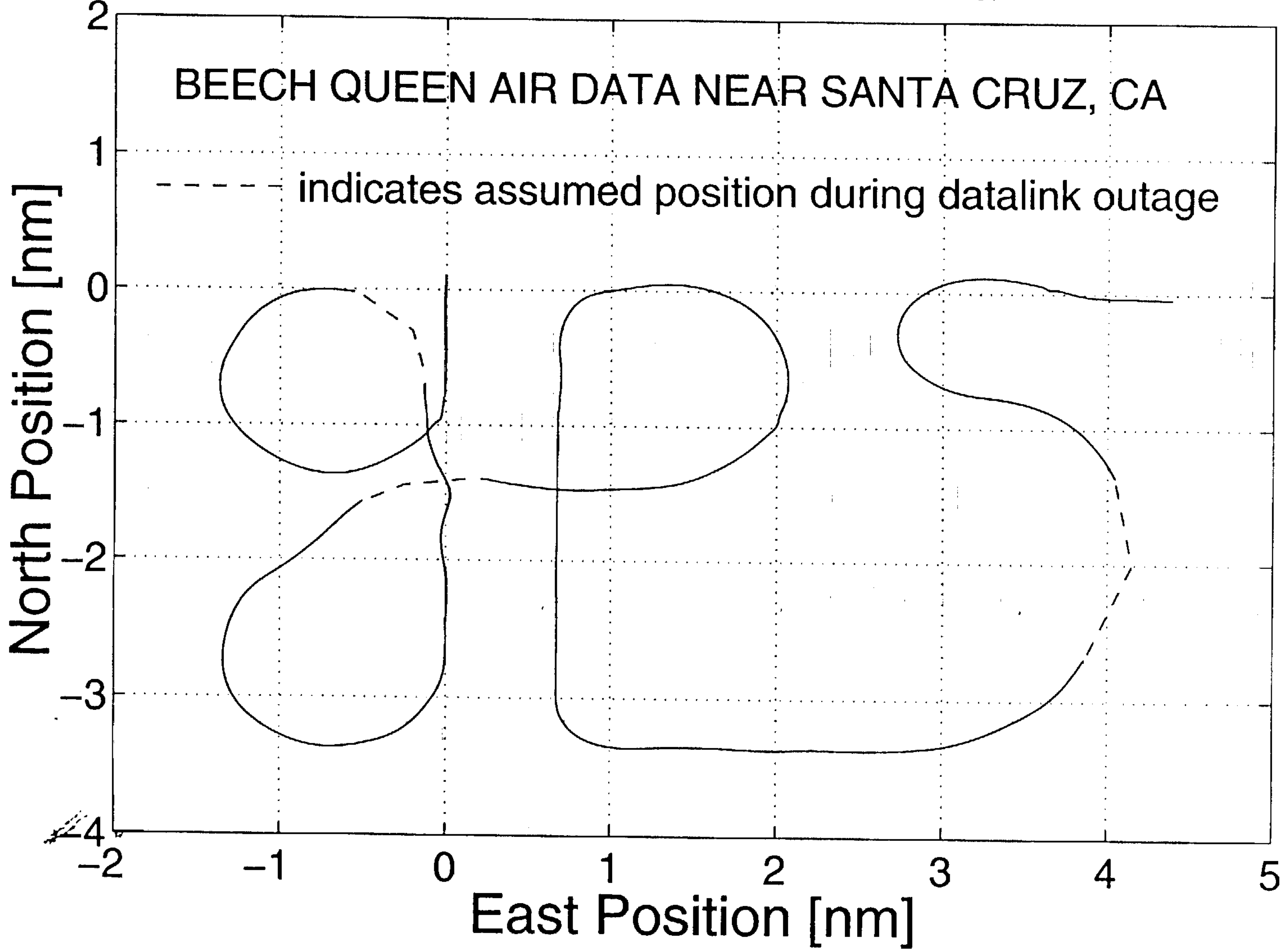



Curved Approaches
Deviation for Traffic
Nominal Center of Turn
Moffett Field
Runway 32L
Smooth Reaquisitions
Left 360 Turn
for Traffic
Along Runway Position [nm]
Cross Runway Position [nm]
−4
−3
−2
−1
0
1
2
−1
0
1
2
3
4


Traffic Patterns
TIGHT PATTERNS USED FOR NOISE ABATEMENT
Left Traffic Runway 32L
Datalink
Dropouts
Moffett Field
Runway 32L
Runway 32R
Right Traffic Runway 32R
Datalink
Dropouts
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
Cross Runway Position [nm]
−2
−1.5
−1
−0.5
0
0.5
1
1.5
2
Along Runway Position [nm]


Tight Traffic Patterns
RUNWAY 32R THRESHOLD DISPLACED 0.75 NM
FOR MAXIMUM NOISE ABATEMENT
Left Traffic Runway 32L
Moffett Field
Runway 32L
Runway 32R
Datalink
Dropouts
Right Traffic Runway 32R
Cross Runway Position [nm]
Along Runway Position [nm]
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2
−1.5
−1
−0.5
0
0.5
1
1.5
2

Extremely Complex Flight Path



Conclusions

- Pilots learned to fly with the display very quickly
- Flight testing demonstrated enhanced accuracy and situational awareness
- The Tunnel Display provided easily-interpreted pilot guidance on flight paths far more complex than current procedures
- Flight tests demonstrated suitability to remote sensing and forest fire fighting
- Safety and utility can be improved across a wide spectrum of aviation

Stanford's Approach

- Gain extensive, ongoing flight experience to supplement simulator display research
- Rapid prototyping heritage
- Build knowledge base on difficult issues that didn't seem difficult initially:
  - DGPS sensor fusion for high-bandwidth human-in-the-loop operations
  - Algorithms for fast AND accurate 3-D navigation and graphics
- Address needs of initial users
  - May not be in passenger operations

Acknowledgments

THANKS TO...

- Roger Hayward, Demoz Gebre-Egziabher, and Matthew Schwall for attitude sensing and video production
- The Stanford WAAS group for position sensing
- Trimble Navigation for the attitude receivers
- The Federal Aviation Administration for sponsoring this work

Microvision, Inc.

The Virtual Retinal Display

The Future of Display Technology

MICROVISION

The Display Challenge

- High quality displays are large, power-hungry and costly
  - Prohibits portability and mobility
  - Limits access to high quality images
- Miniature displays lack image quality and are still costly!
  - Image quality is lost as displays are miniaturized

Single Scan 5/2-03

MICROVISION

The Virtual Retinal Display™

Microvision's Virtual Retinal Display™ (VRD™) enables light weight, low power, and high performance display systems for a wide range of applications.

MICROVISION

The Company

- Seattle company founded in 1993
- Funded Virtual Retinal Display R & D with the University of Washington Human Interface Technology Lab
- Currently transferring technology to the marketplace
- Initial public offering August 1996 raised over $18 Million in capital

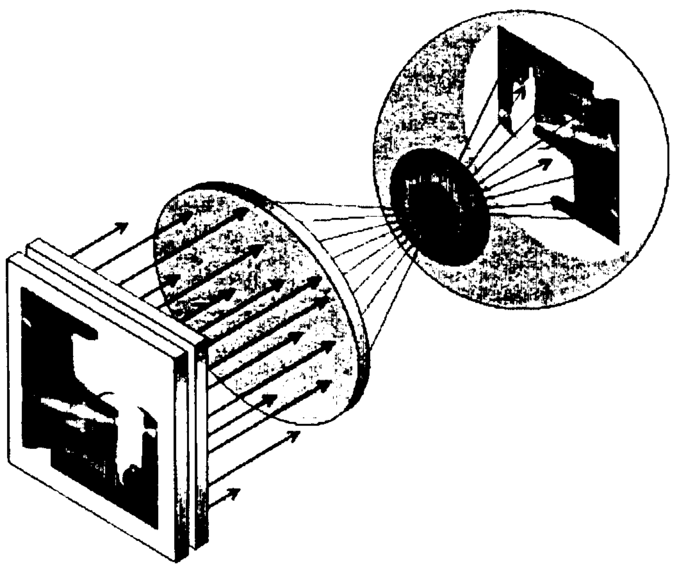
MICROVISION

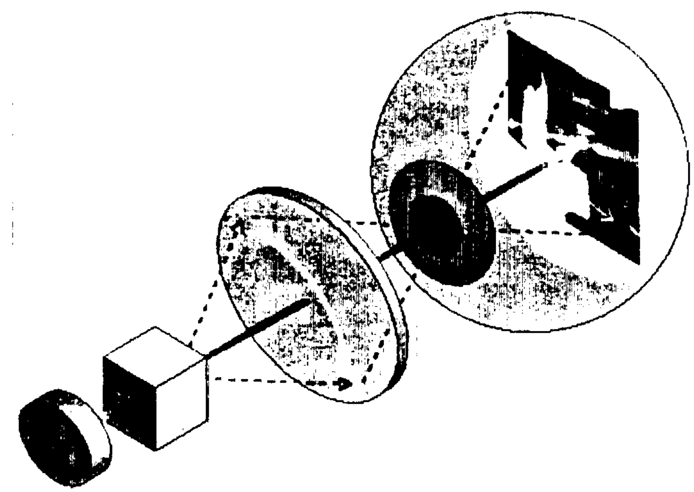
Proprietary Position

- 6 Patents Issued
- 7 Applications currently pending
- Over 30 Inventions selected for patenting in 1997
- 1998 Target of 20-30 new applications filed

MICROVISION

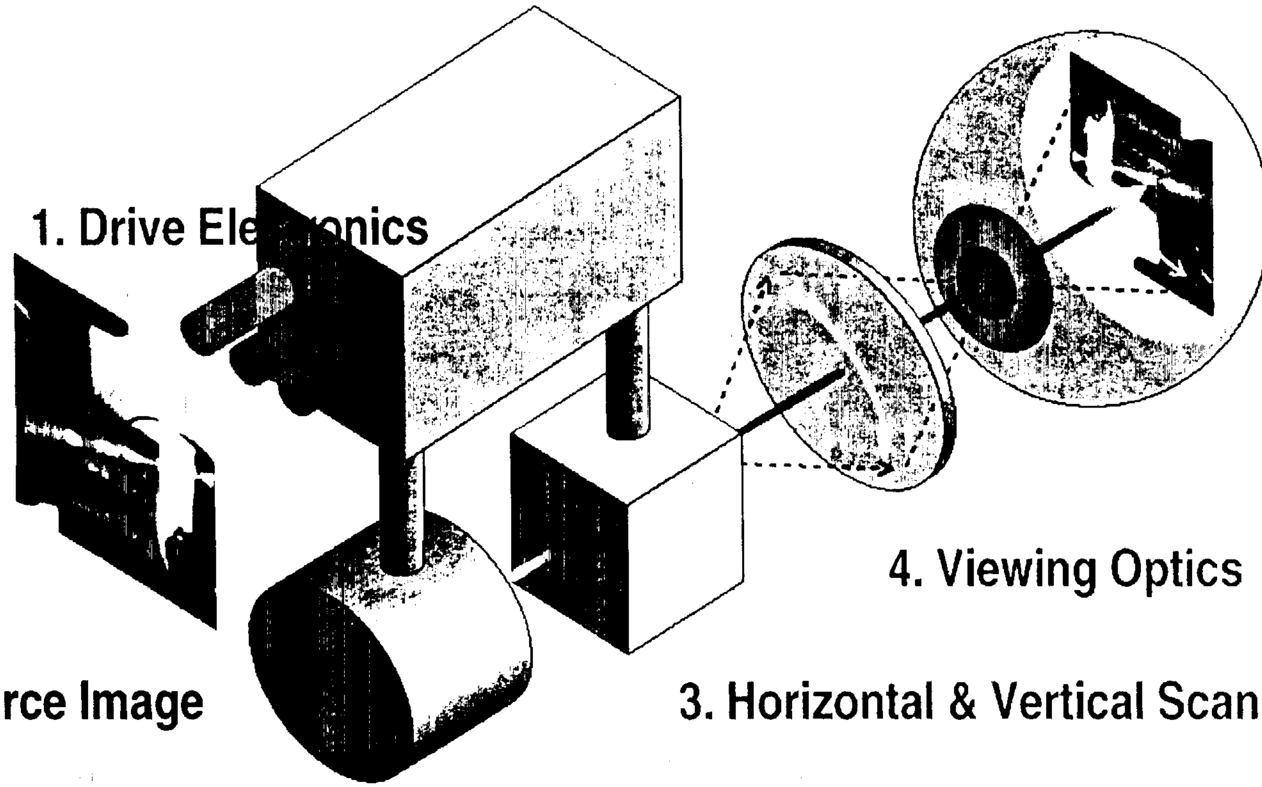
VRD vs. Flat Panel Display (CRT)





MICROVISION

VRD System Diagram



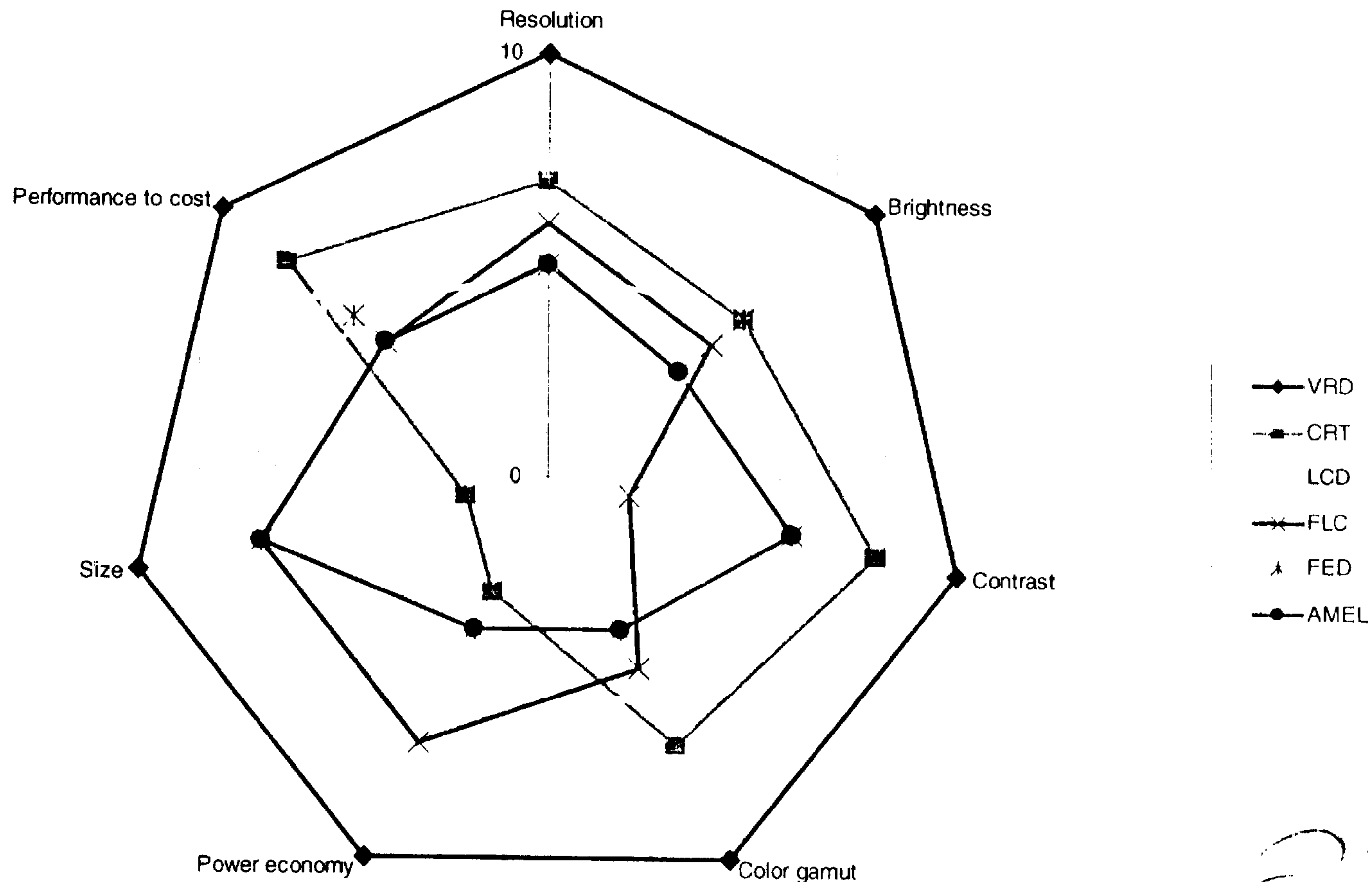
MICROVISION

VRD - Something New Under the Sun

- Unlimited Brightness, Contrast, and Color Gamut means Vision-Like Electronic Display Quality
- Advanced Parallel Processing and Display means Scalable Spatial Resolution
- Modular System Architecture Means Economical Product Evolution
- Miniature VRD "Engines" will Revolutionize HMD and Large Screen Projection Developments

MICROVISION

VRD Technology Comparison



MICROVISION

Microvision, Inc. Accomplishments

- 1995 Demonstrated Color VGA VRD
- 1996 Demonstrated Monochrome Red VGA Portable with EPE
- 1997 Delivered Monochrome Red and Full Color VGA VRDs with EPEs, hand-held and helmet mounted, to Boeing Co., Saab, and Commercial Aerospace Customer

MICROVISION

Technology/Program Timeline

	Today	Q1 98	Q2 98	Q3 98	Q4 98	Q4 99	Q1 00	Q4 00
Program/ Application				Airecrew Integrated Systems "Comanche" (Rotorcraft)	Battle Command Battle Lab (C4I)	Rotorcraft Simulation	C4I Wide FOV	Rotorcraft Simulation
Resolution	VGA	SVGA	XGA	XGA	XGA	HDTV	XGA	XGA
Color	Monochrome & RGB			Monochrome Green	RGB	Monochrome Green	RGB	RGB
FOV	30°x22° (Single eye)			52°x30° (2 eye/ partial overlap)	30°x22° (2 eye/full overlap)	30° circular	60° circular+	52°x30° (2 eye/partial overlap)
Exit Pupil	15mm			15mm	10mm	1-15mm+	15mm+	15mm+
Mounting	HMD			HMD	Head-Worn	HMD	Eye-Glasses	HMD
Optics	Beam Splitter			Beam Splitter	Beam Splitter	Beam Splitter	Beam Splitter	Beam Splitter

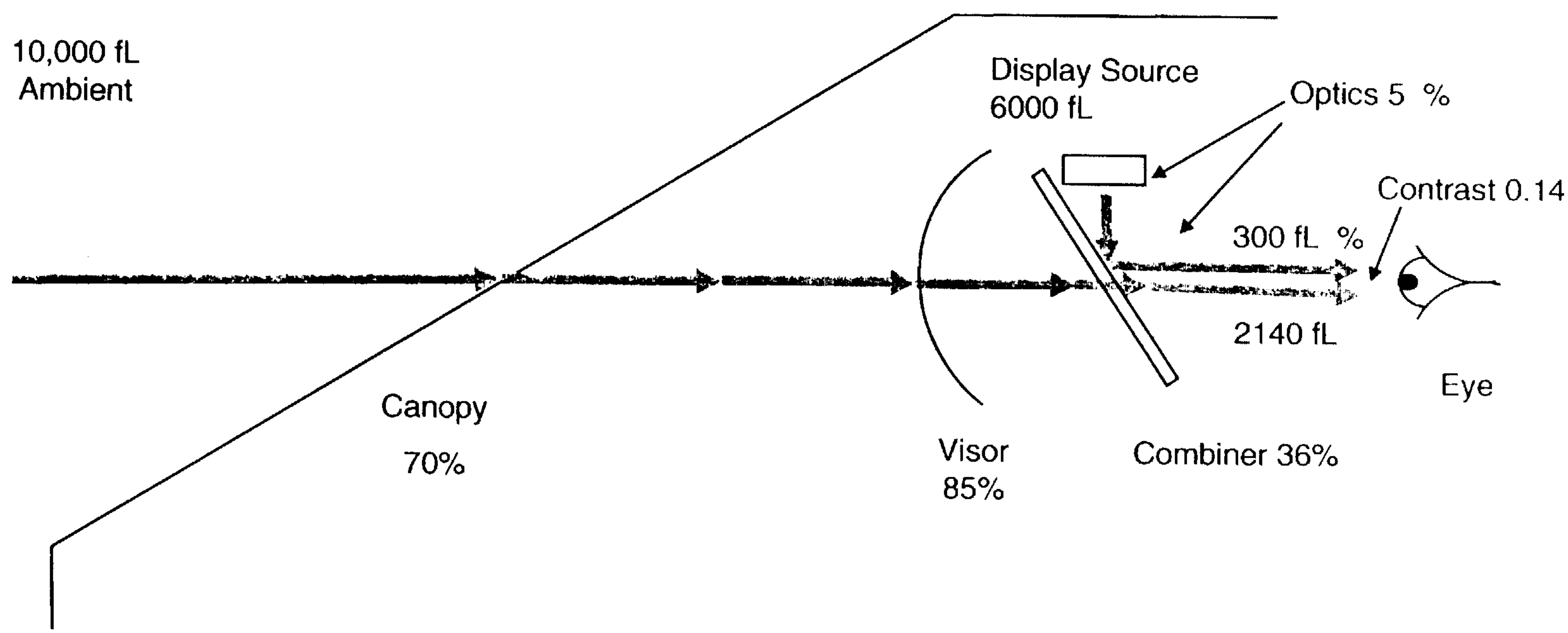
MICROVISION

Eye Safety

- UW Human Subjects Review Committee, August 1995
- Interim Safety Release provided by David H. Sliney, Ph.D., Chief, Laser Branch, US Army Environmental Hygiene Agency, June 1996
- Technical Paper published October 1997 by Dr. Erik Viirre, M.D., Ph.D. - Permanent member of VRD staff at the UW Human Interface Technology Laboratory
  - Laser Safety Analysis of a Retinal Scanning Display System (Journal of Laser Applications)

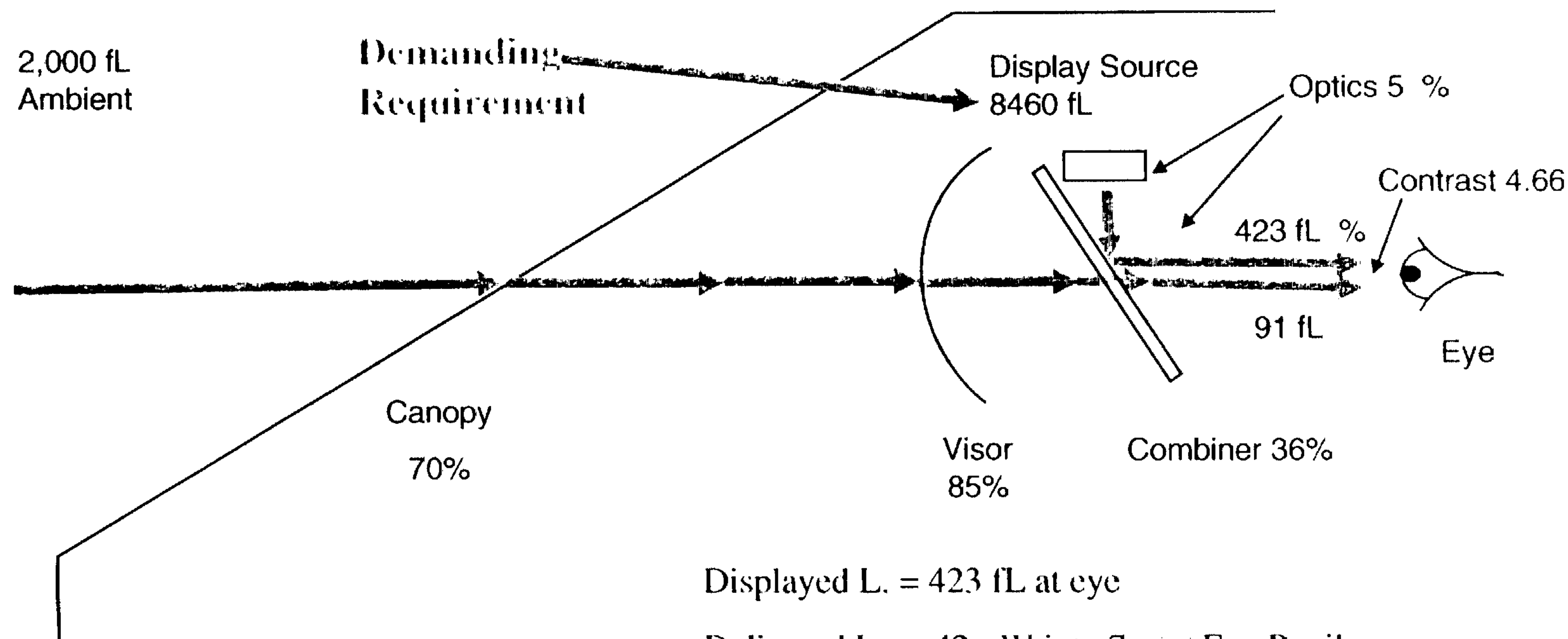
MICROVISION

Luminance Analysis for Symbology



MICROVISION

Luminance Analysis for Raster



Displayed L. = 423 fL at eye

Delivered L. = 42μ W into 7 mm Eye Pupil

ANSI MPE = 195μ W into 7 mm Eye Pupil

MICROVISION

Eye Safety - Conservative Analysis

- Consider the case of a Green, 532 nm display at 423 fL, with a 41°x35° FOV (vs. the eye's entire FOV)
- Assume 7mm eye pupil (normally expect 2mm at 423 fL)
- Result is 42 microwatts into eye's pupil (maximum)
- Analysis based on ANSI Z126.1-1993 *American National Standard for Safe use of Lasers* places MPE at 195 microwatts (assumes all day continuous use)
- In this application, the VRD:
  - Is Eye-Safe at the Required Luminance
  - Has Additional Failure Modes to Compensate
  - Has No Invisible Energy Created

MICROVISION

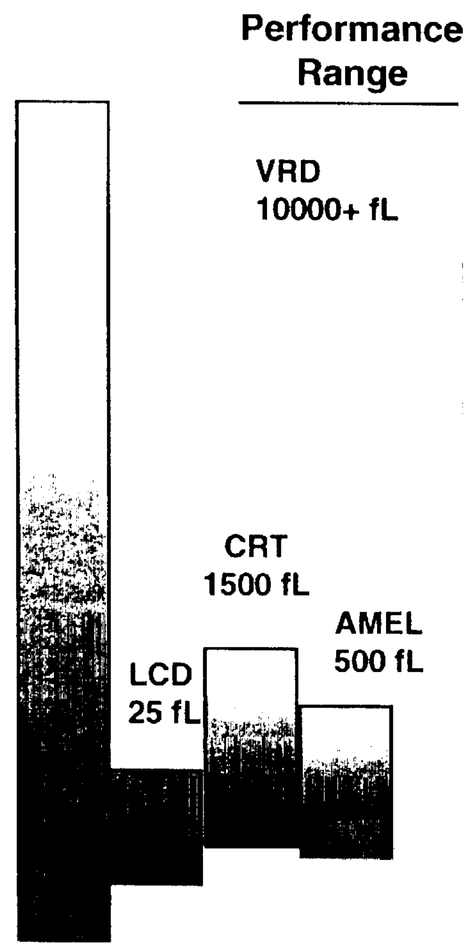
VRD = Vision-Like Image Quality

- Luminance limited only by Eye-Safety Restrictions
- Effectively Infinite Contrast
- Easily Scaled to Ultra-High Spatial Resolution
- Effectively Unlimited Color Gamut

MICROVISION

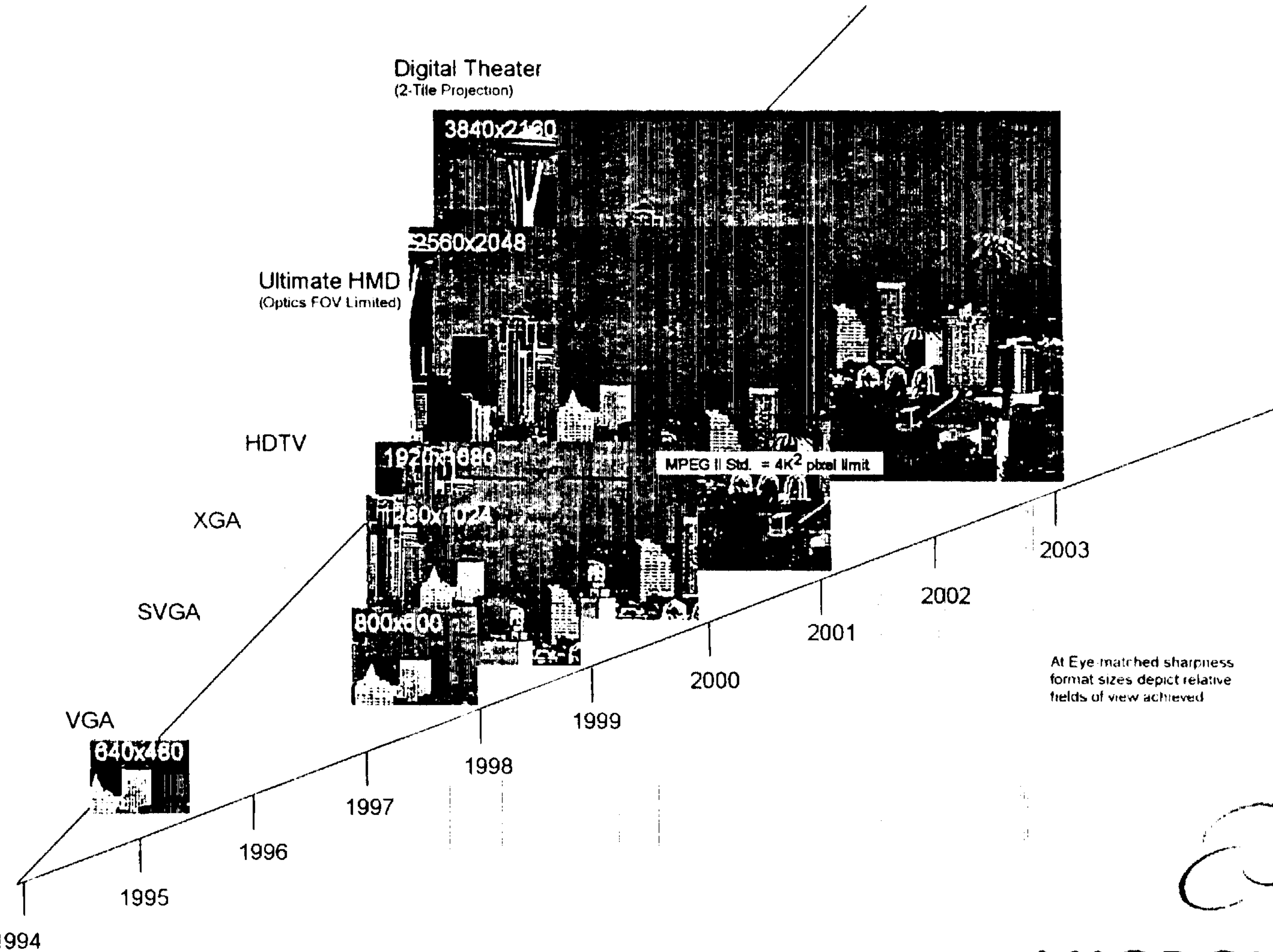
VRD Dynamic Range Performance

VRD light power (microwatts)
6000 - 20000 μW
600 - 2000 μW
12 - 200 μW
< 2 μW



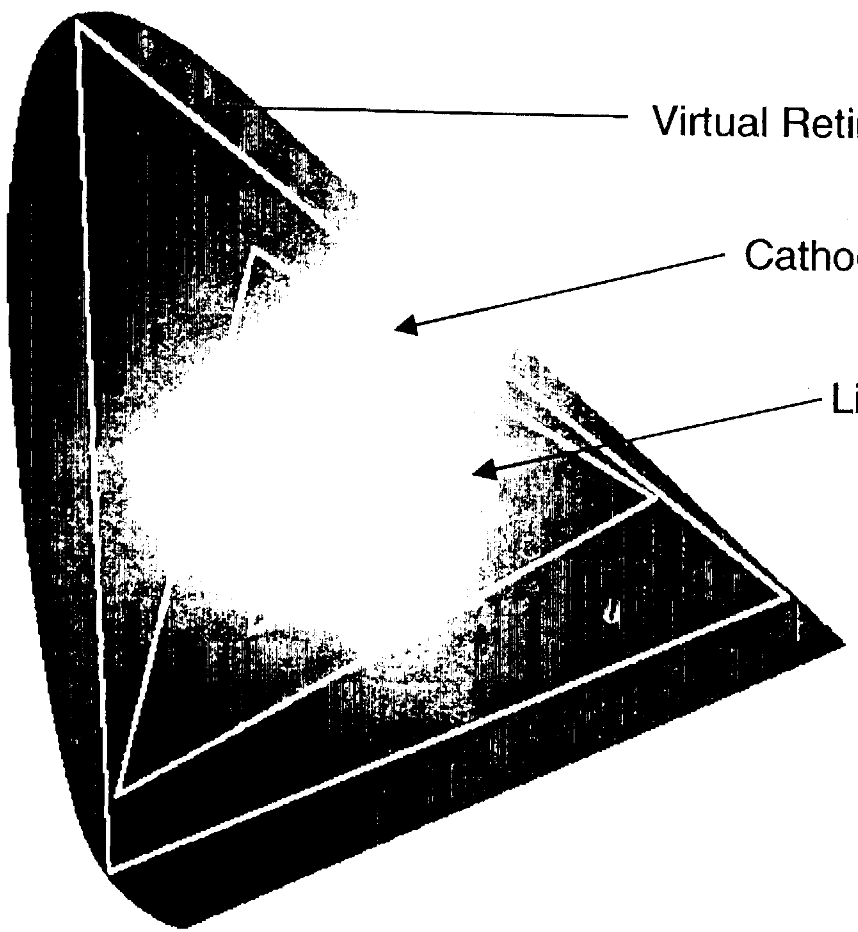
MICROVISION

Resolution (Pixel Count) Road Map



MICROVISION

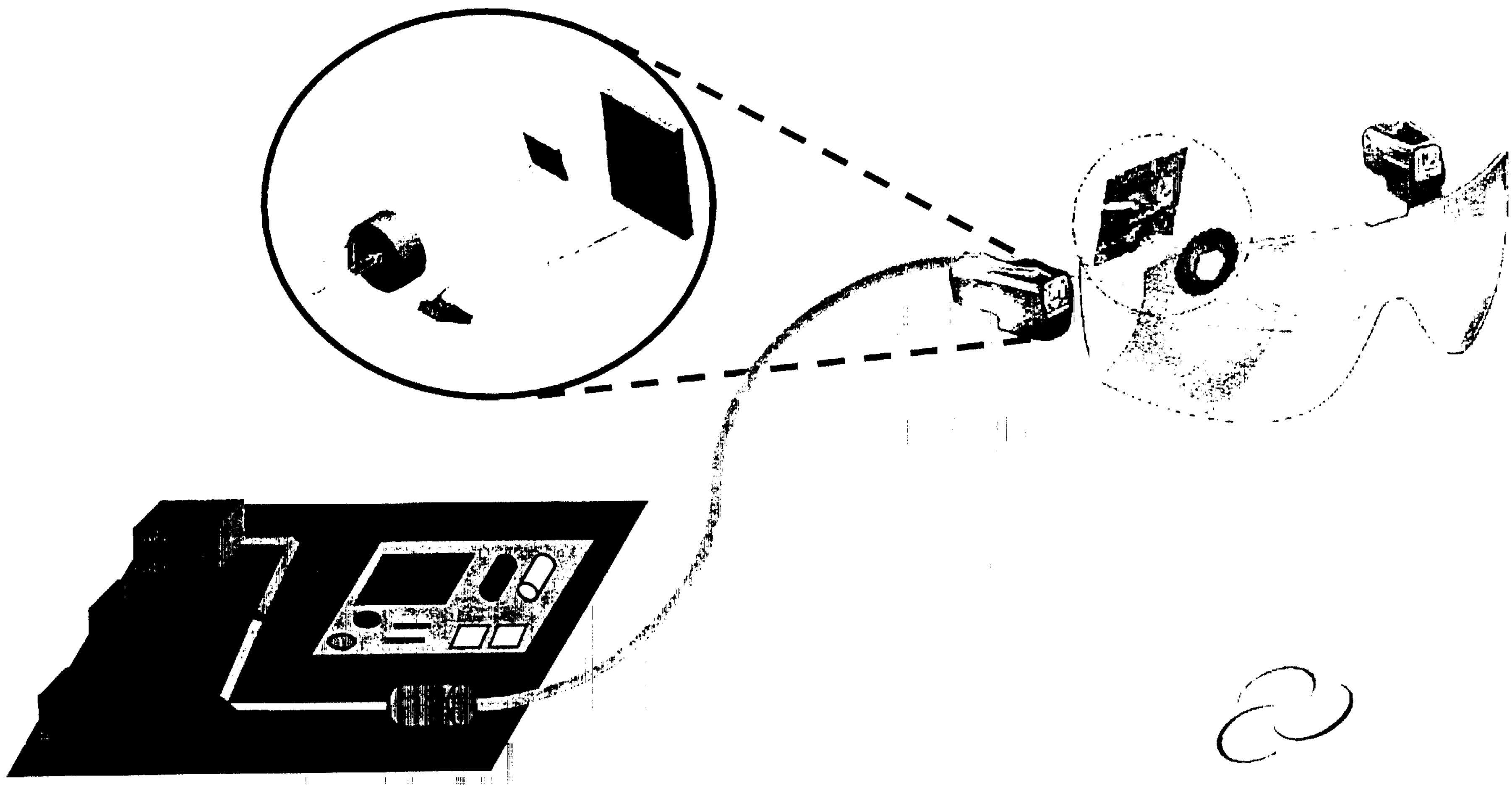
VRD Color Gamut



CIE Chromaticity Chart
Limited only by
Light SourceAvailability

MICROVISION

VRD System Detail



MICROVISION

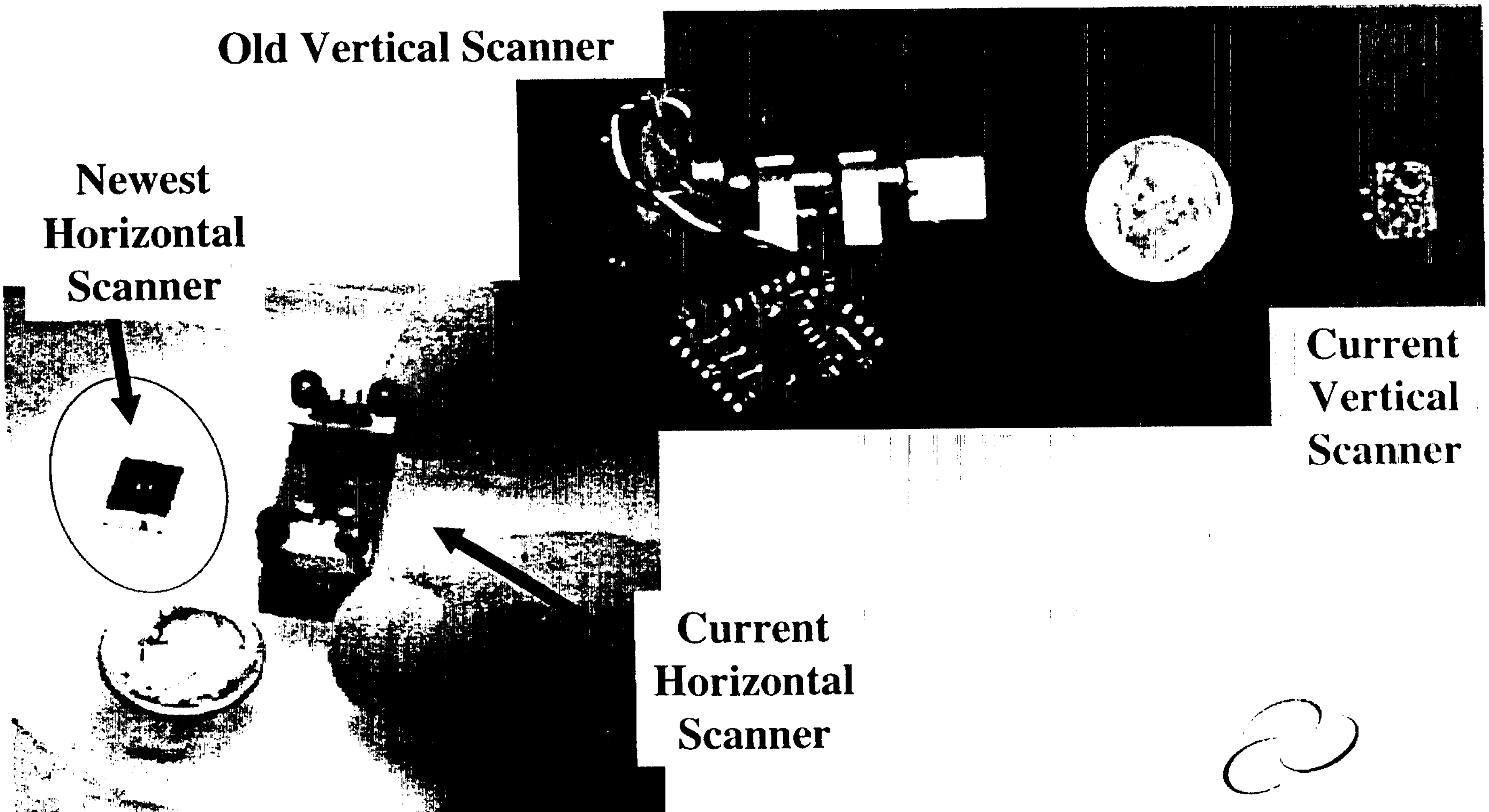
Light Sources

	TODAY	THIS YEAR	2-5 YEARS
	Gas lasers	Diode-Pumped Solid-State Lasers	Laser Diode
Volume:	450 in^3	10 in^3	1 in^3
Input Power:	2 kWatts	50 Watts	100 mWatts
Weight:	24 lbs.	3 lbs.	4 oz.
Modulation:	External	External	Direct

S Willey 1/16/98

MICROVISION

Scanners Drive Performance, Size, and Cost



MICROVISION

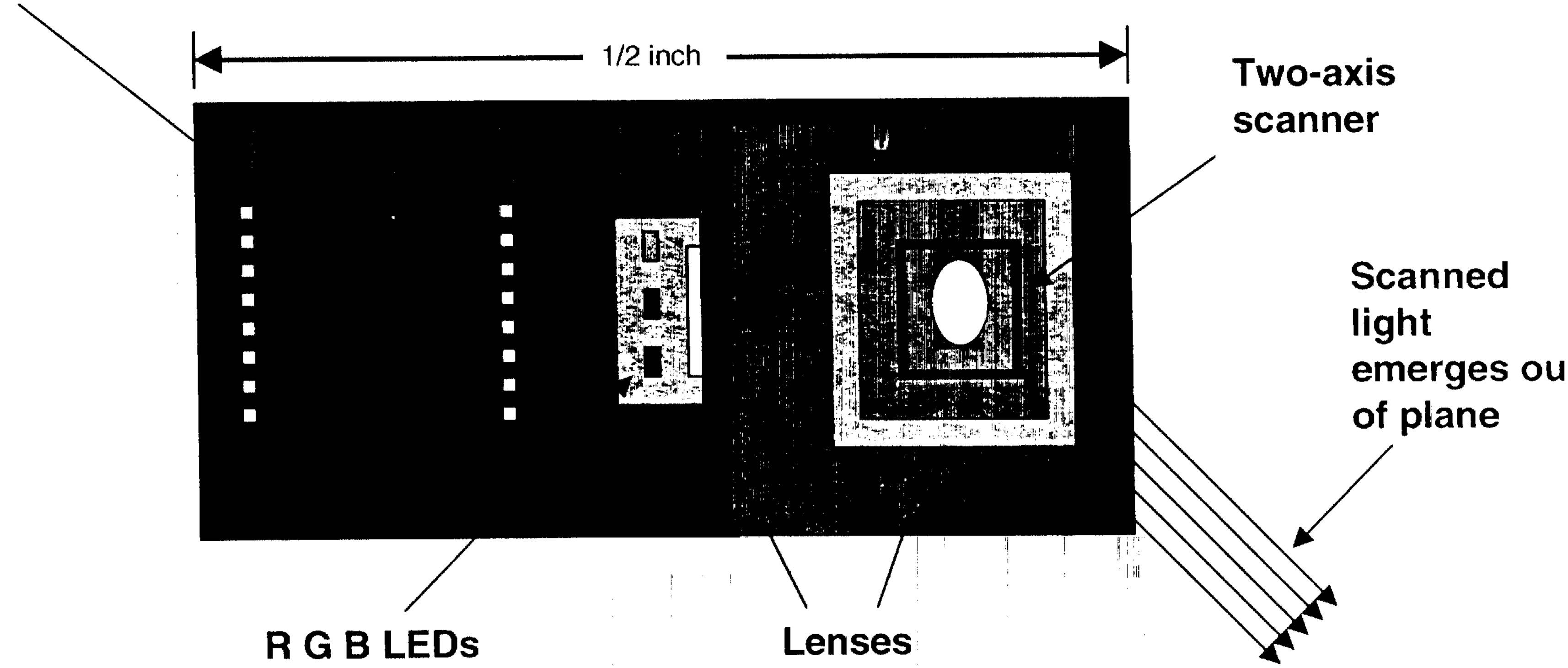
Weight

Item	mass, g
Fiber end	.4
Collim lens	.1
Feed mirror	.1
MRS mirror	.2
MRS spring	.7
MRS base	3.0
Vscan mirror	.2
Vscan body	2.6
Chas fib, len fs ss	2.3
Pup exp	1.9
FF lens	2.1
Rigid cone & shell	1.1
Wire equiv	.2
Total Projector	14.6

Total Projector	14.6
Eye Couple Optic	30.0
Support	30.0
Total, <u>One Eye</u>	74.6

MICROVISION

Advanced VRD



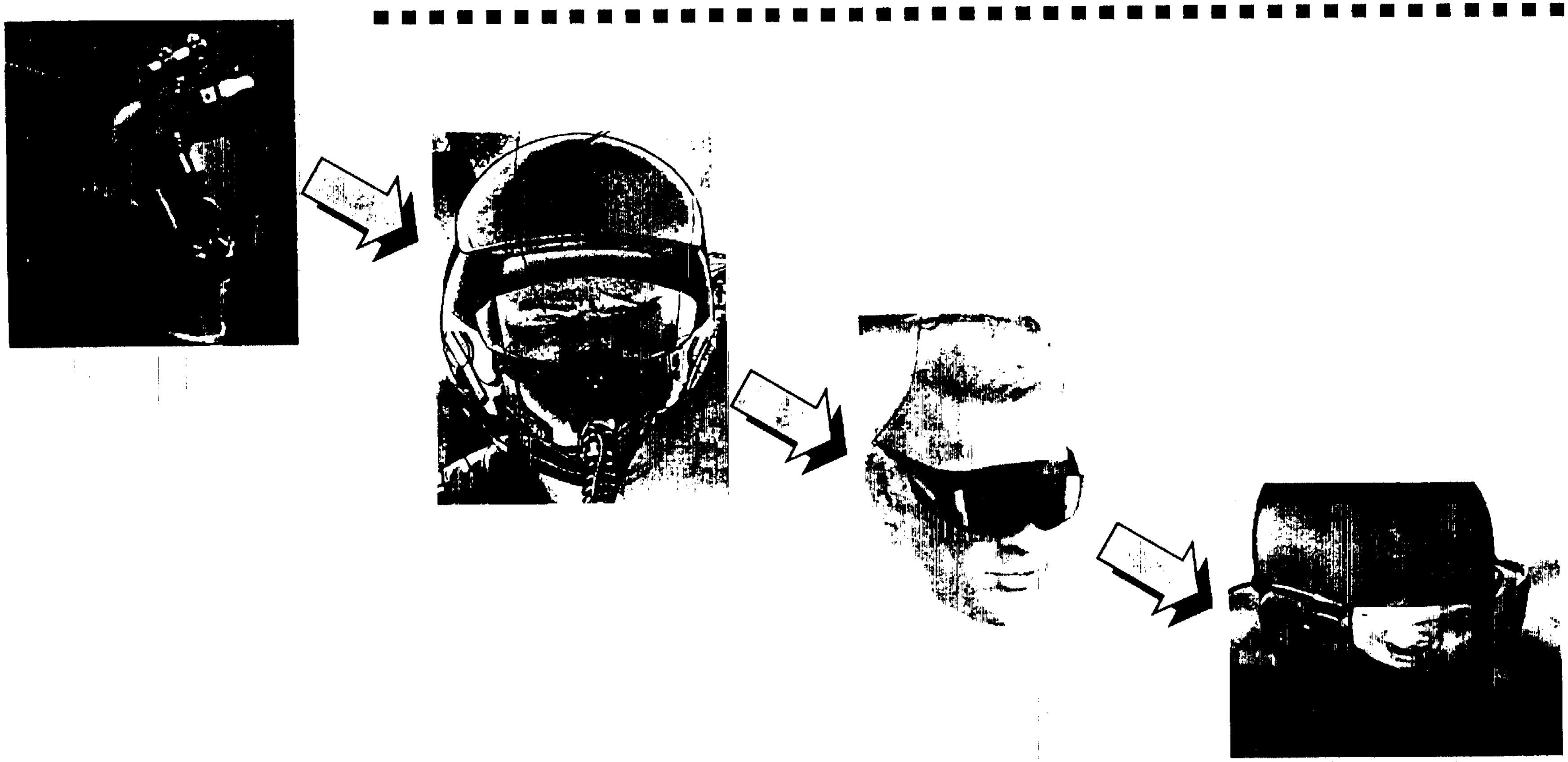
MICROVISION

Virtual Retinal Display: A Superior Image Source

- Optical Expansion of Beam -> Exit Pupil Enlargement
- Integrated Eye and Scene Tracker Concepts
- Modular System Architecture
- Miniaturizable Components
- Parallel Image Data Processing and Display
- Virtual or Real Image Projection

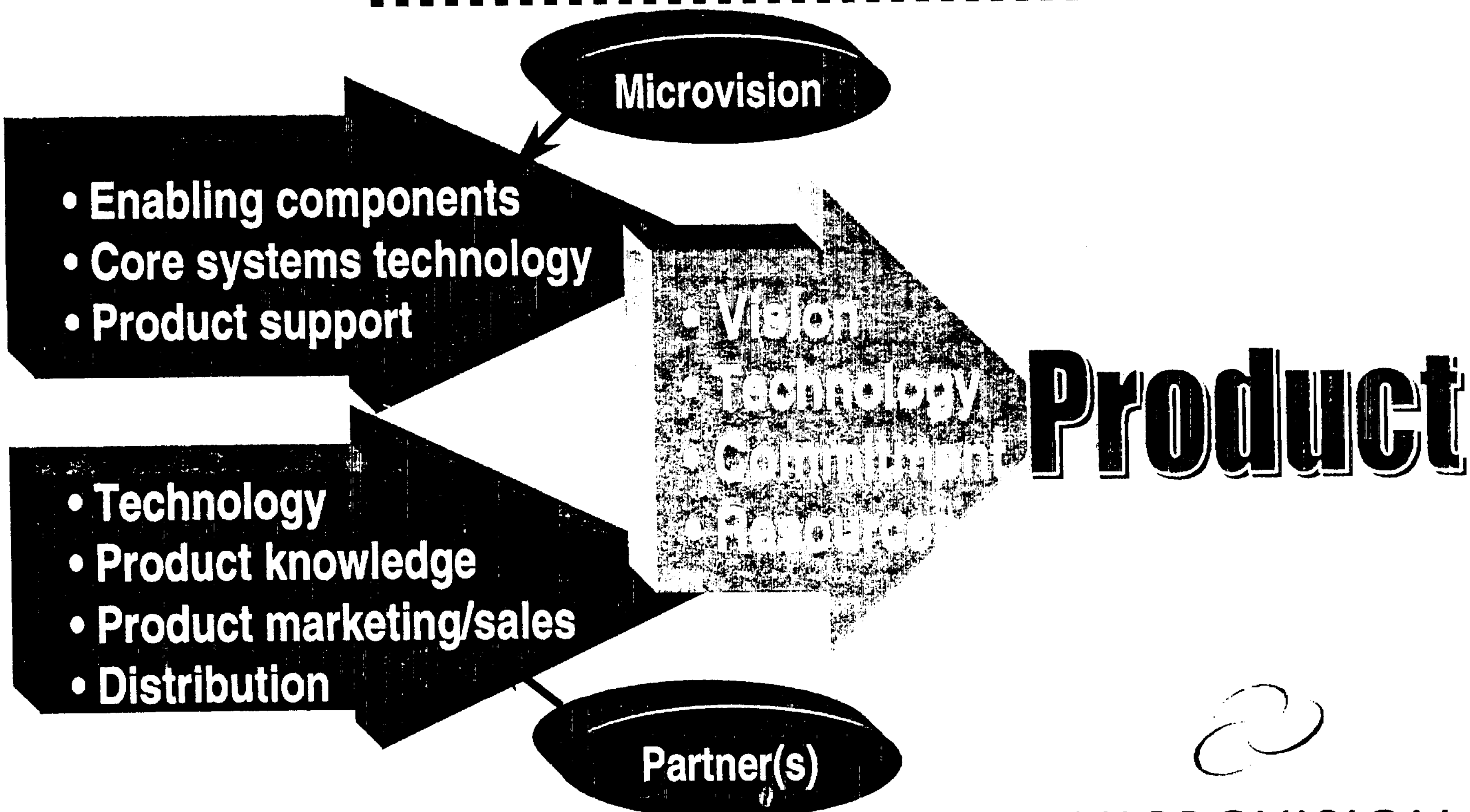
MICROVISION

Display Evolution



MICROVISION

Co-Development Roadmap



MICROVISION

In Summary

- The VRD is a High Performance, Scalable Technology
- The VRD is Developing Rapidly to Final Commercialization
- The VRD will Meet Military and Commercial Aerospace Needs

MICROVISION

S13-03

Synthetic Vision Workshop 2
January 28, 1998

"Visualization In The GA Cockpit"

Ray Wabler
Advanced Creations, inc.
Dayton Ohio

The ACi Mission

The Mission of Advanced Creations, inc. (ACi) is to create a revolutionary advance in flight safety through the application of pilot-oriented avionics technology. Our goal is to mitigate the most common pilot induced errors, the number one cause of aviation fatalities.

OASIS Overview

The *O*nboard *A*vionics *S*ynergistic *I*nformation *S*ystem

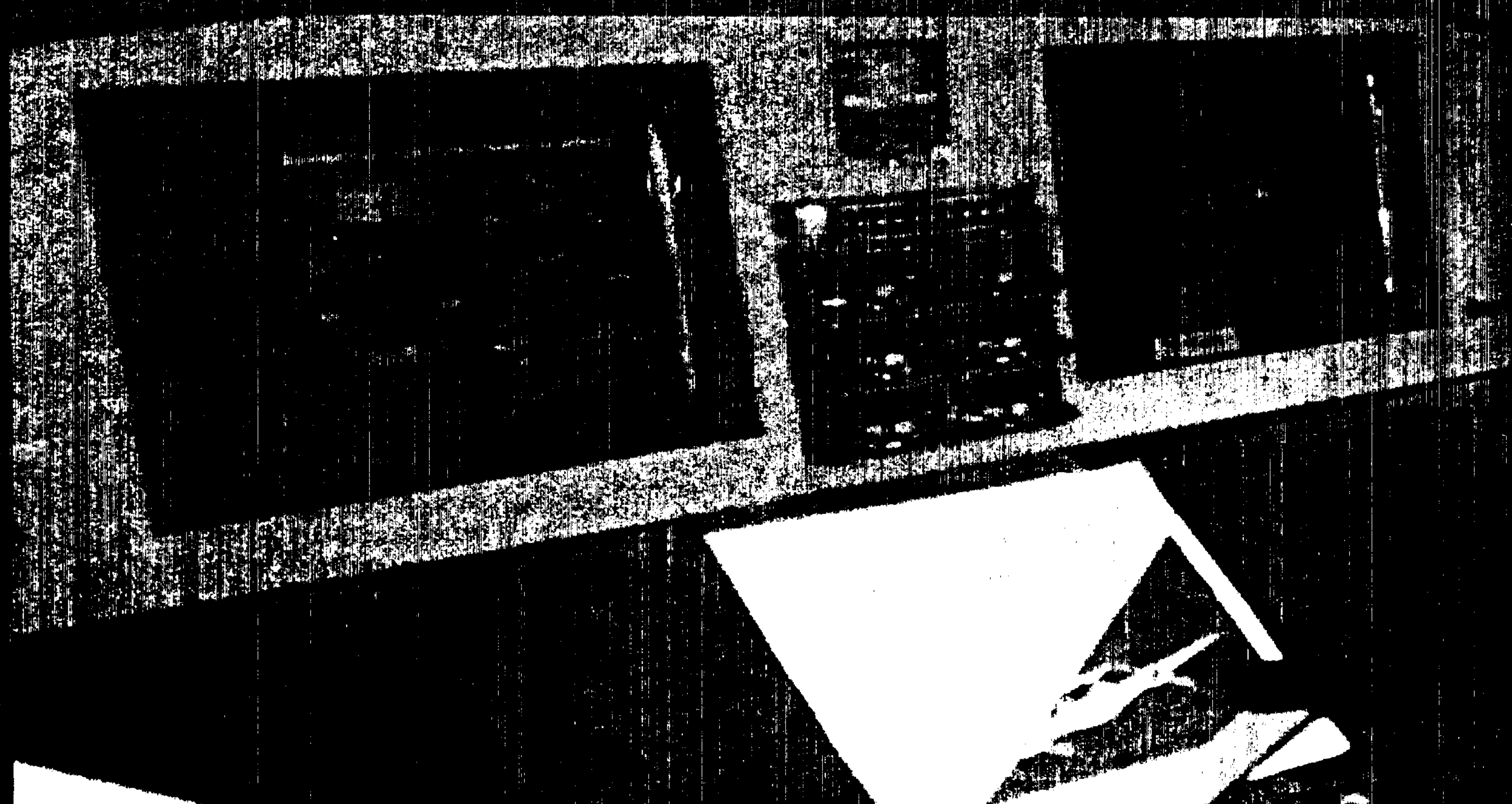
OASIS Is:

- Next Generation Avionics System
- Total Synergistic Integration
- Provides A Synthetic View of World
- Improves Safety Through Training
- Designed With Human Factors As A Requirement -- Not An Afterthought

The Need For OASIS

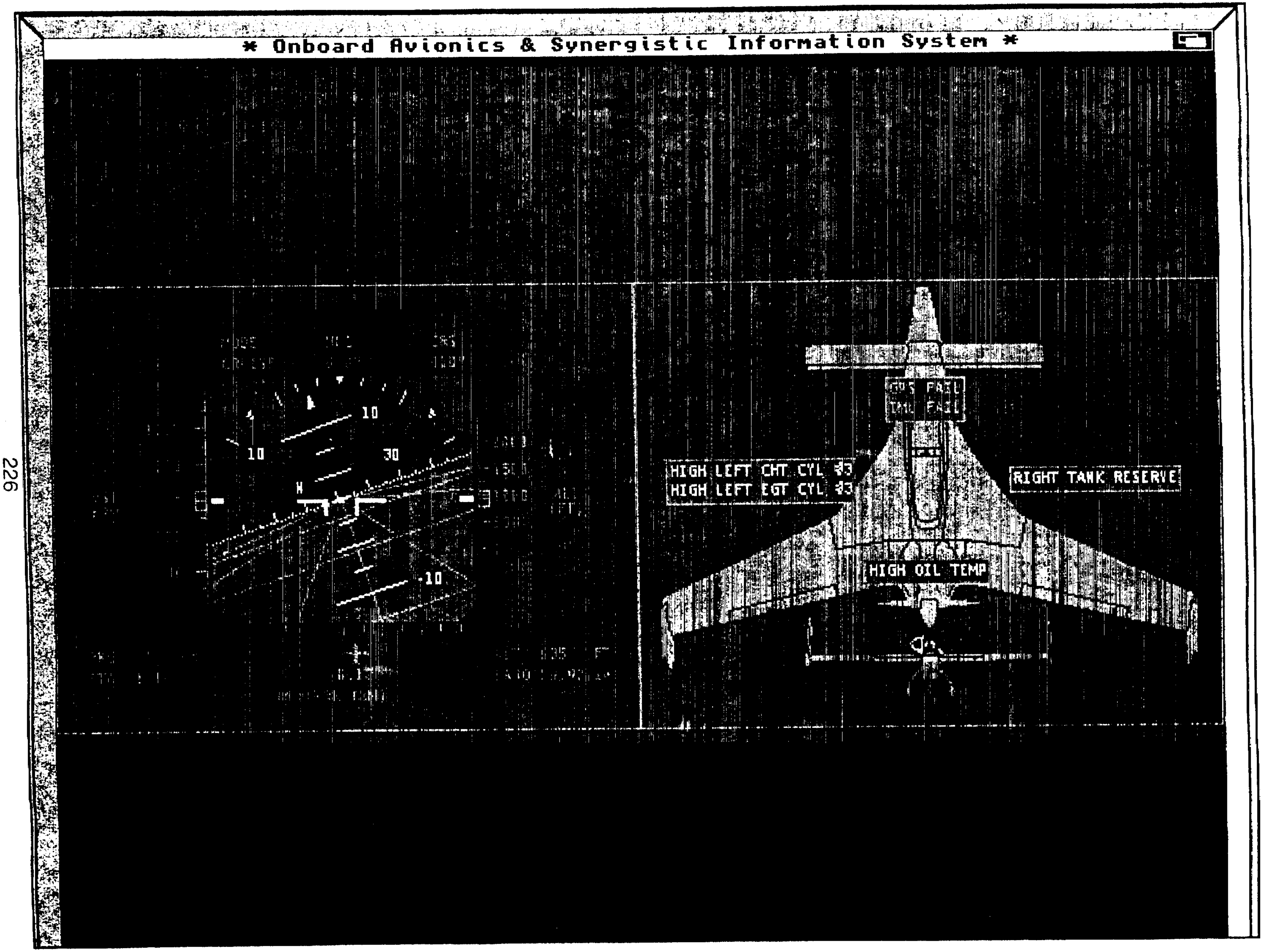
Improved ***Safety Of Flight*** With The Added Benefits Of ***Reduced Pilot Workload*** In The Cockpit.

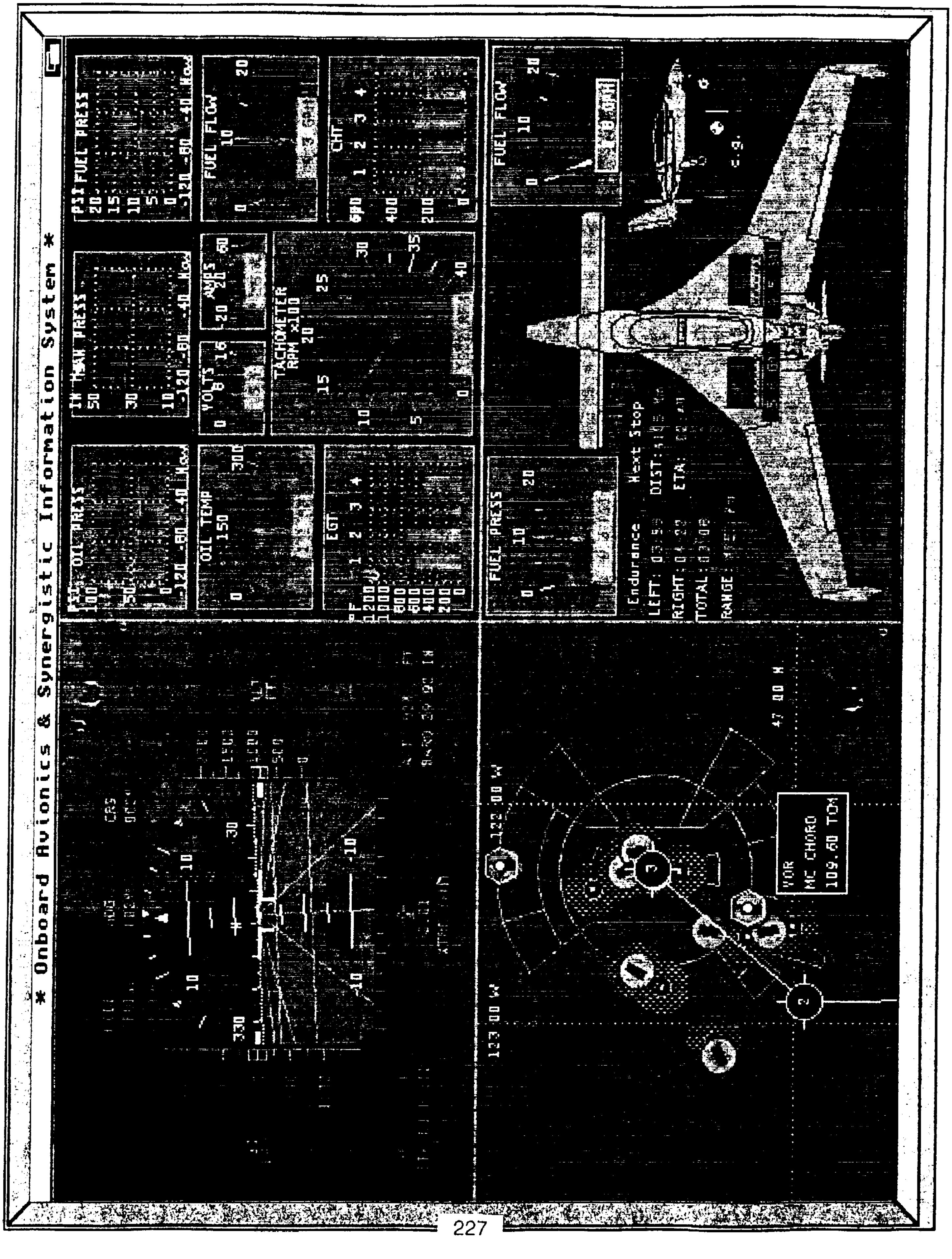
OASIS @ Oshkosh `97



January 28, 1998 Advanced Creations, inc. 6

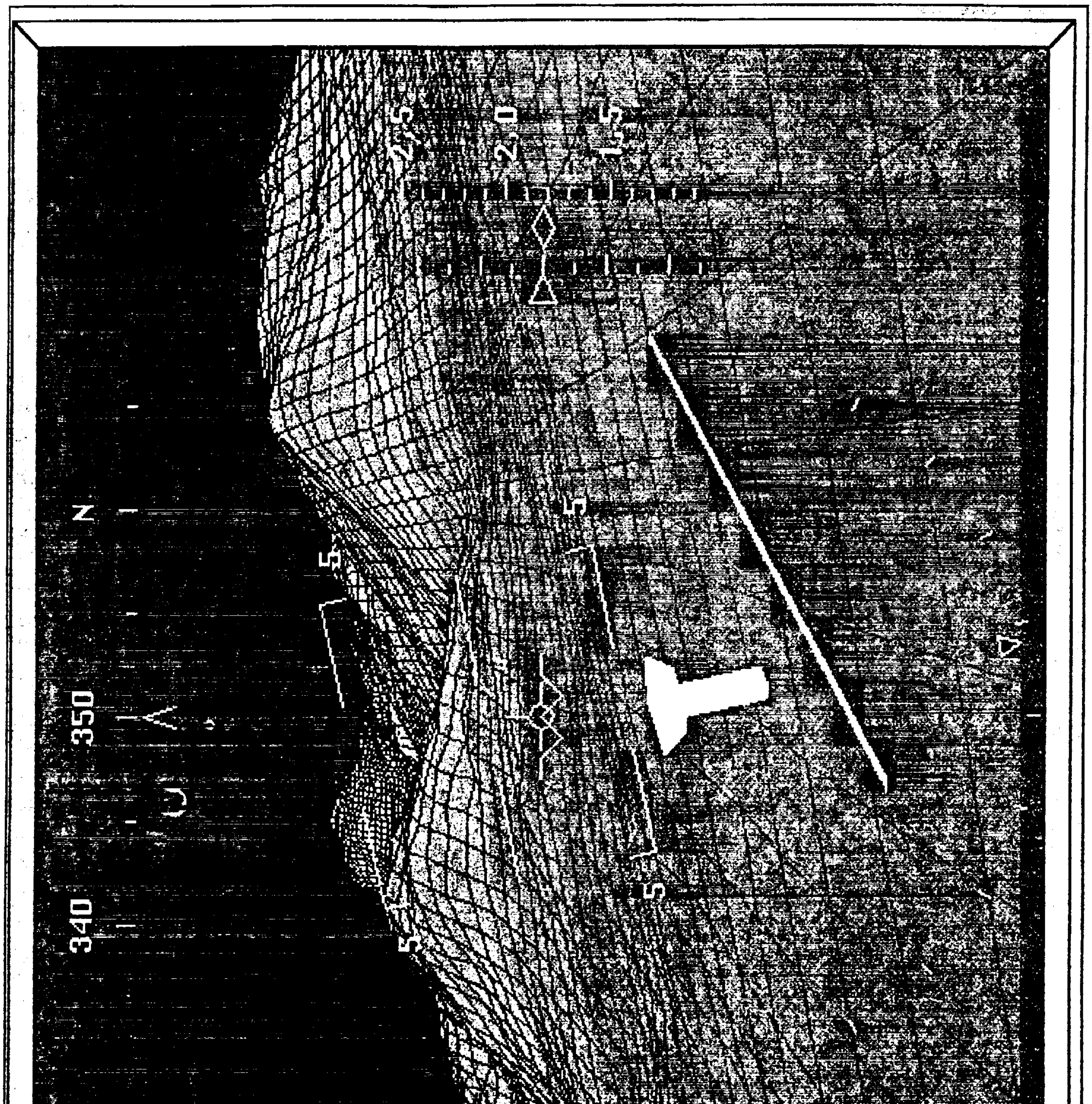
Critical Systems/Status Monitoring

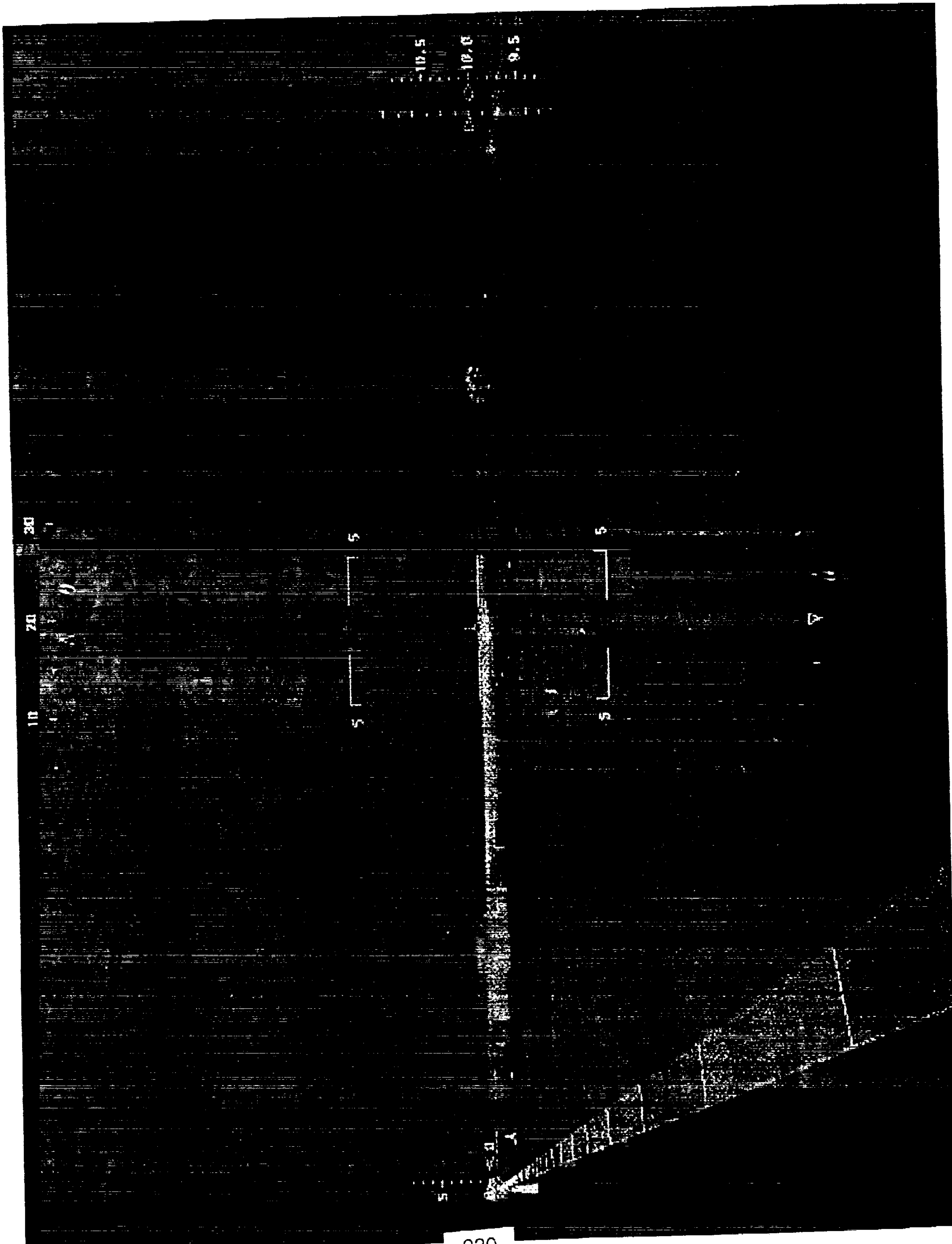

* Onboard Avionics & Synergistic Information System *
10
10
30
-10
HIGH LEFT CHT CYL #3
HIGH LEFT EGT CYL #3
RIGHT TANK RESERVE
HIGH OIL TEMP

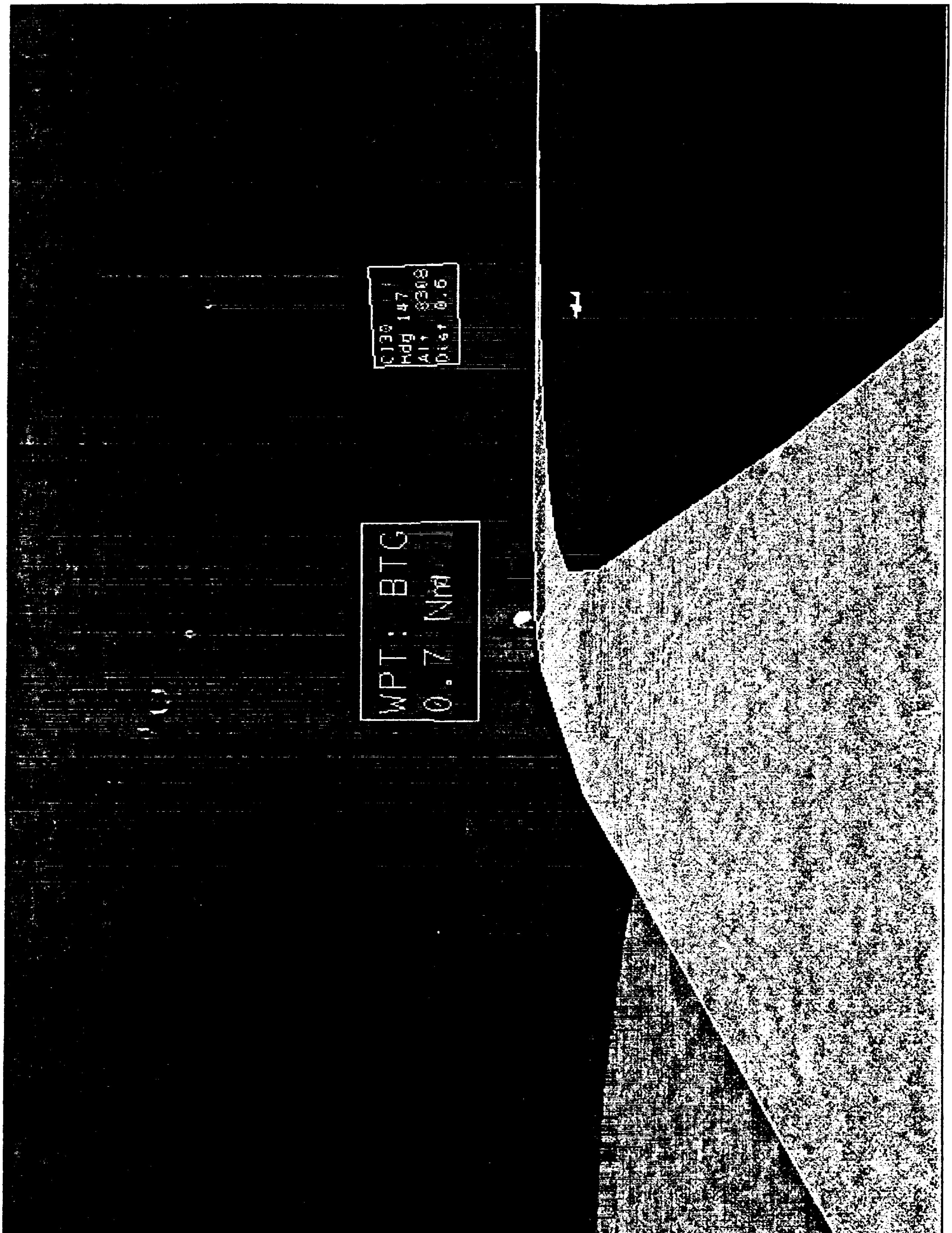

* Onboard Avionics & Synergistic Information System *
OIL PRESS
OIL TEMP
EGT
IN HG MAN PRESS
VOLTS
AMPS
TACHOMETER
RPM x100
PSI FUEL PRESS
FUEL FLOW
CHT
FUEL PRESS
Endurance
Next Stop
LEFT:
RIGHT:
TOTAL:
RANGE
DIST:
ETA
VOR
MC CHORD
109.60 TOM
123 00 W
122 00 W
47 00 N

Situation Awareness & Terrain Avoidance

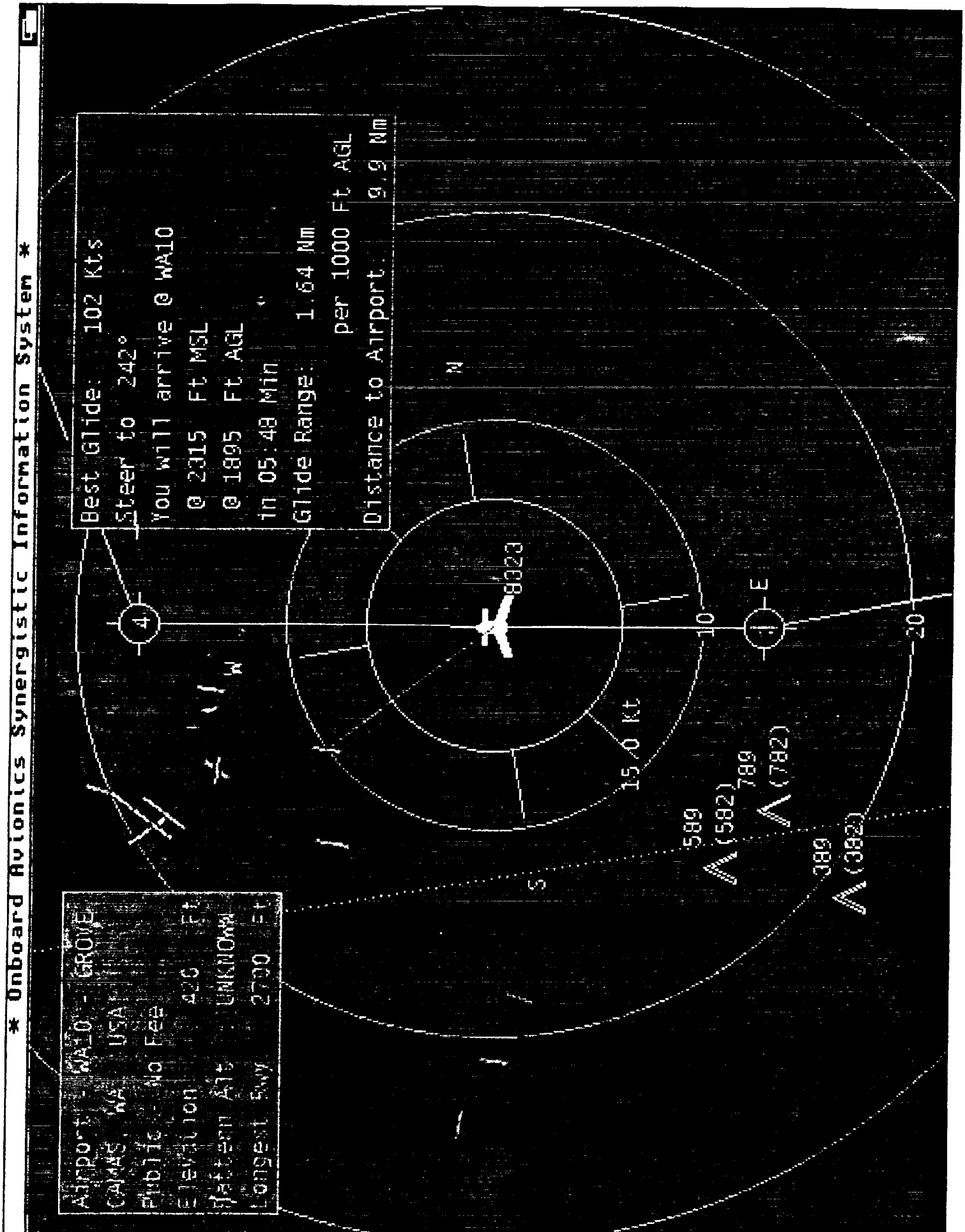
Pathway in the Sky & Flight Cues

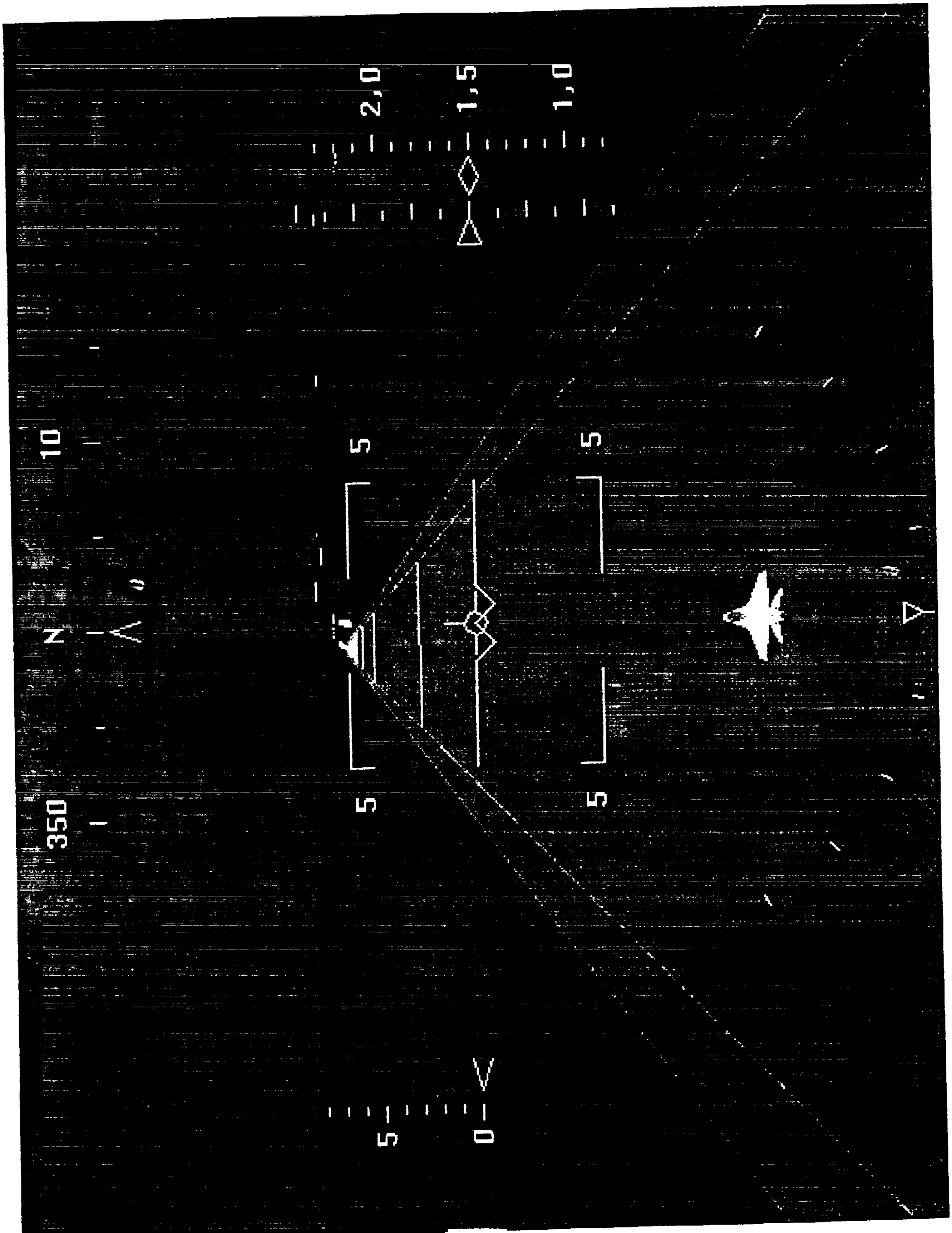

340
350
N
15
2.5
2.0
1.5
5




C130
Hdg 147
Alt 0308
Dist 0.6
WPT: BTG
0.7 NM

Emergency Management


* Onboard Avionics Synergistic Information System *
Airport - WA10 - GROVE
CAMAS, WA USA
Public - No Fee
Elevation 420 Ft
Pattern Alt UNKNOWN
Longest Rwy 2700 Ft
Best Glide: 102 Kts
Steer to 242°
You will arrive @ WA10
@ 2315 Ft MSL
@ 1895 Ft AGL
In 05:48 Min
Glide Range: 1.64 Nm
per 1000 Ft AGL
Distance to Airport 9.9 Nm
N
E
S
W
10
20
15.0 Kt
8323
4
1
589
(582)
789
(782)
389
(382)


350
N
10
5
5
5
5
2,0
1,5
1,0
5
0

OASIS Summary

- Dramatically Improves Safety of Flight
  - Reduces Pilot Workload
  - Synthetic Vision Provides Comprehensive Situation Awareness
  - Acts as an Extra Set of "Eyes" in the Cockpit for Watching Flight Critical Data
  - Fly-Through Rehearsal Capability Helps Prevent "Surprises" & Provides Training Aides
  - Better "Information" for Improved Decision Making

Single scan 5/4-03

NAVAIR

GROUND PROXIMITY WARNING SYSTEM FOR HELICOPTERS (GPWS CATEGORY III)

CUBIC DEFENSE SYSTEMS, INC.

PMA-209

OUTLINE

- Purpose of Briefing
- CFIT Analysis
- Safety Recognition
- Program Background
- GPWS Description
- Summary

PMA-209

PURPOSE OF BRIEFING

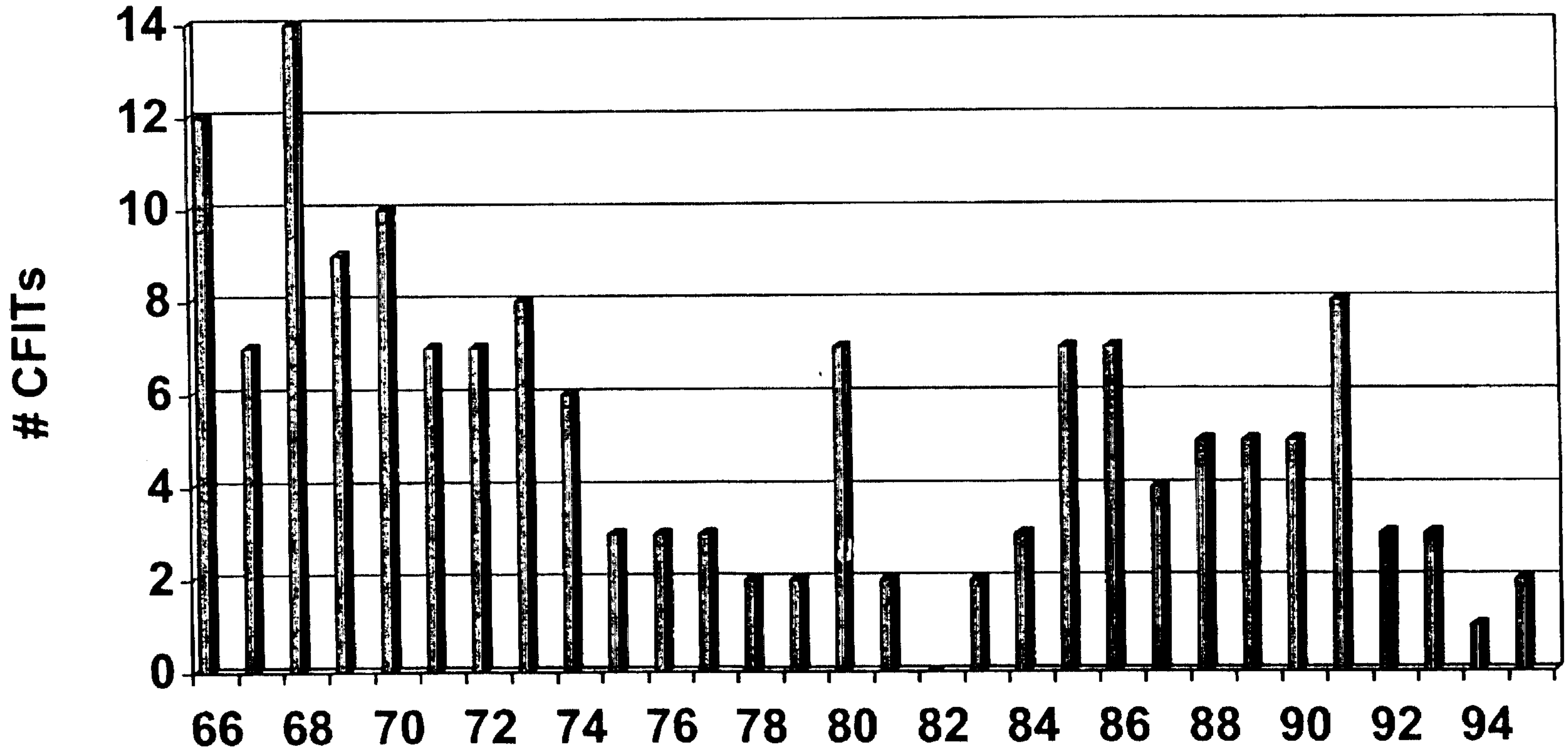
- Define Controlled Flight Into Terrain (CFIT) Problem
- Provide overview of PMA-209's GPWS Program
- Describe GPWS Category III

PURPOSE OF GPWS

To prevent CFIT mishaps and the resultant loss of lives and aircraft.

- CFITs occur when a capable pilot loses situational awareness and unintentionally flies a functional aircraft into the terrain

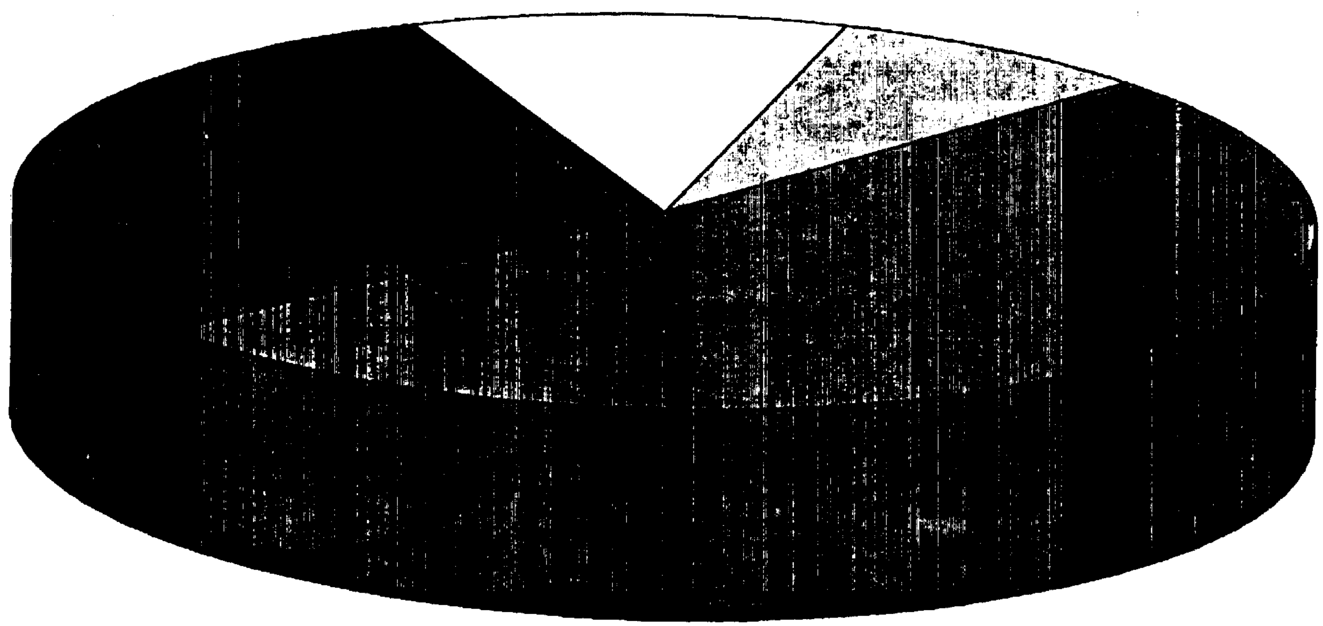
USN/USMC HELO CFITs *
(1966-95)



* *Based on Naval Safety Center (NSC) accidents statistics*

PMA-209

HELO CFIT ANALYSIS*
TERRAIN TYPE



* *Based on NSC accidents statistics*

JOINT RECOGNITION OF CFITs

<u>Sept 1990 Jt. Services Review Committee (JSRC)</u>
"A GPWS is needed to provide the pilot with timely warning of unintentional or unsafe closure with the ground or water."

<u>March 1997 HQ USAF- Lt.Gen. Jumper, Dep.Chief of Staff, Ops & Plans</u>
The AF Navigation and Safety Master Plan recommends GPWS for all passenger and troop carrying aircraft.

<u>June 1997- Naval Aviation Policy on Aircraft Safety System Avionics</u>
<u>D.V. McGinn, Rear Admiral, Director, Air Warfare</u>
"Beginning immediately, new production and remanufactured aircraft will be equipped with an appropriate FDR/CVR/IMD/GPWS/CAS or functional equivalent."

PMA-209

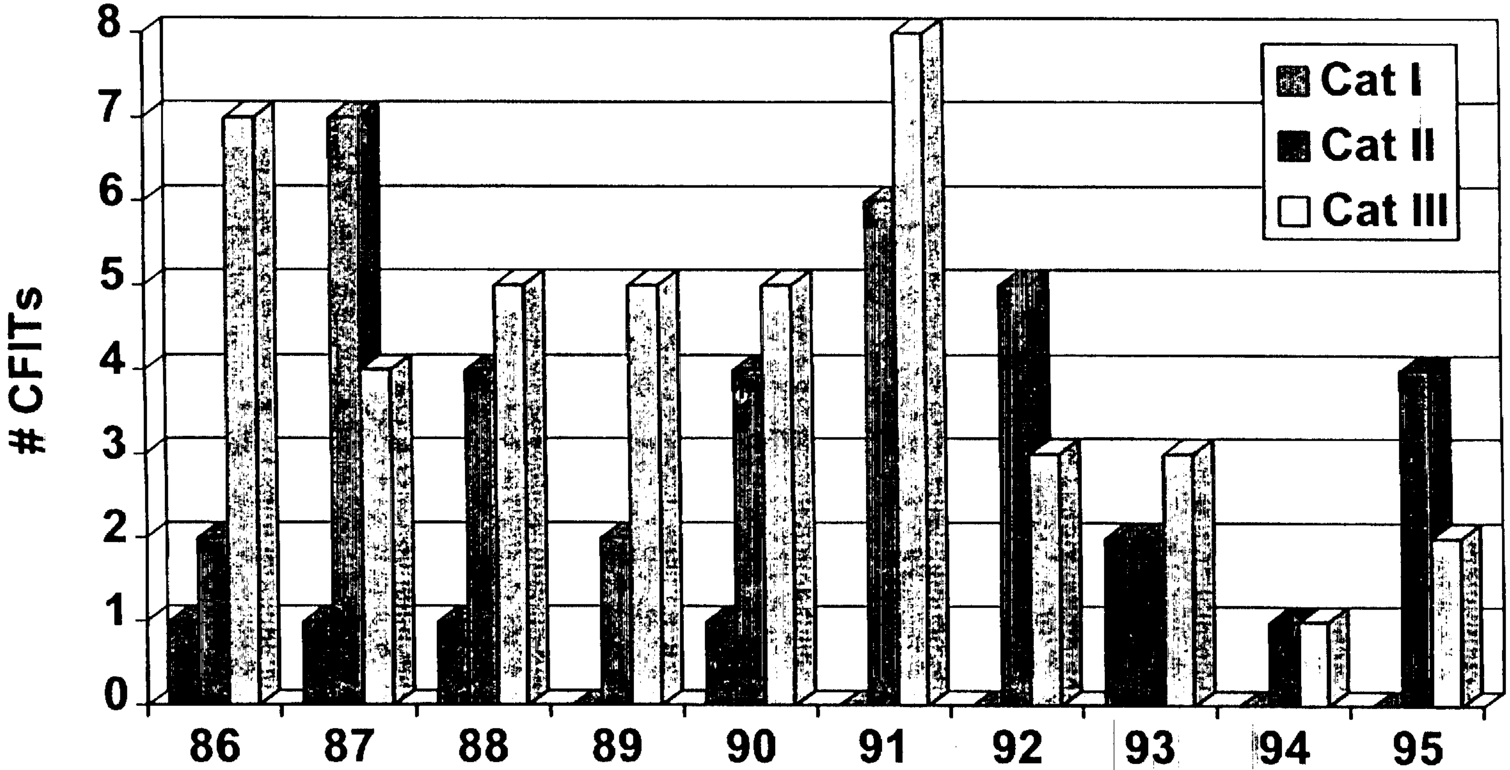
NAVY GPWS PROGRAM
THREE CATEGORIES

Multi-engine:	CAT I	AlliedSignal MkVII (ASN-156) Envelope approach; FAA certified
TACAIR:	CAT II	Navy-developed algorithm embedded in mission computer
Helicopter:	CAT III	Cubic Defense Systems (AYQ-23) Kinematic approach

PMA-209

8

CFIT MISHAPS*



	Cat I	Cat II	Cat III
# CFITs over last 10 yrs:	6	37	43
Avg per year:	0.6	3.7	4.3

* *Based on NSC accidents statistics*

PROGRAM BACKGROUND
GPWS CATEGORY III

- Operational Requirement (OR) #140-05-87
- Competitively awarded, EMD contract to CDS
- CH-53E lead platform
- Completed equipment qualification, A/C integration
- Combined DT/OT completed in May 96. Independent OT successfully completed Aug 96.
- Milestone III approval June 97
- Currently integrating and testing on CH-53D, MH-53E, and CH-46E
- Fully funded OSIP for CH-53D/E, MH-53E, CH-46E, and CH/SH-60

PMA-209

WHAT IS GPWS?

- Safety *back-up* system that warns air crews of impending CFIT
  - *Does not affect how pilot flies*
- Provides voice and visual cues to aircrew

HOW IT WORKS

GPWS samples all sensors to determine dynamic state of the a/c relative to the underlying terrain every 100 msec.

GPWS is Predictive: a/c dynamics, terrain trend, a/c recovery capability, and pilot reaction time are all used in the algorithm to determine and issue a predictive warning to ensure a/c does not penetrate a Minimum Recovery Altitude (MRA)

AIRCRAFT SENSOR INPUTS

- Radar Altimeter
- Roll and Pitch
- Barometric Altitude and Rate
- ILS (Glideslope)
- Engine Torque
- Indicated Airspeed
- Weight on Wheels
- Pilot and Co-Pilot RADALT bug setting
- Landing Gear Position

PMA-209 14

GPWS REQUIREMENTS

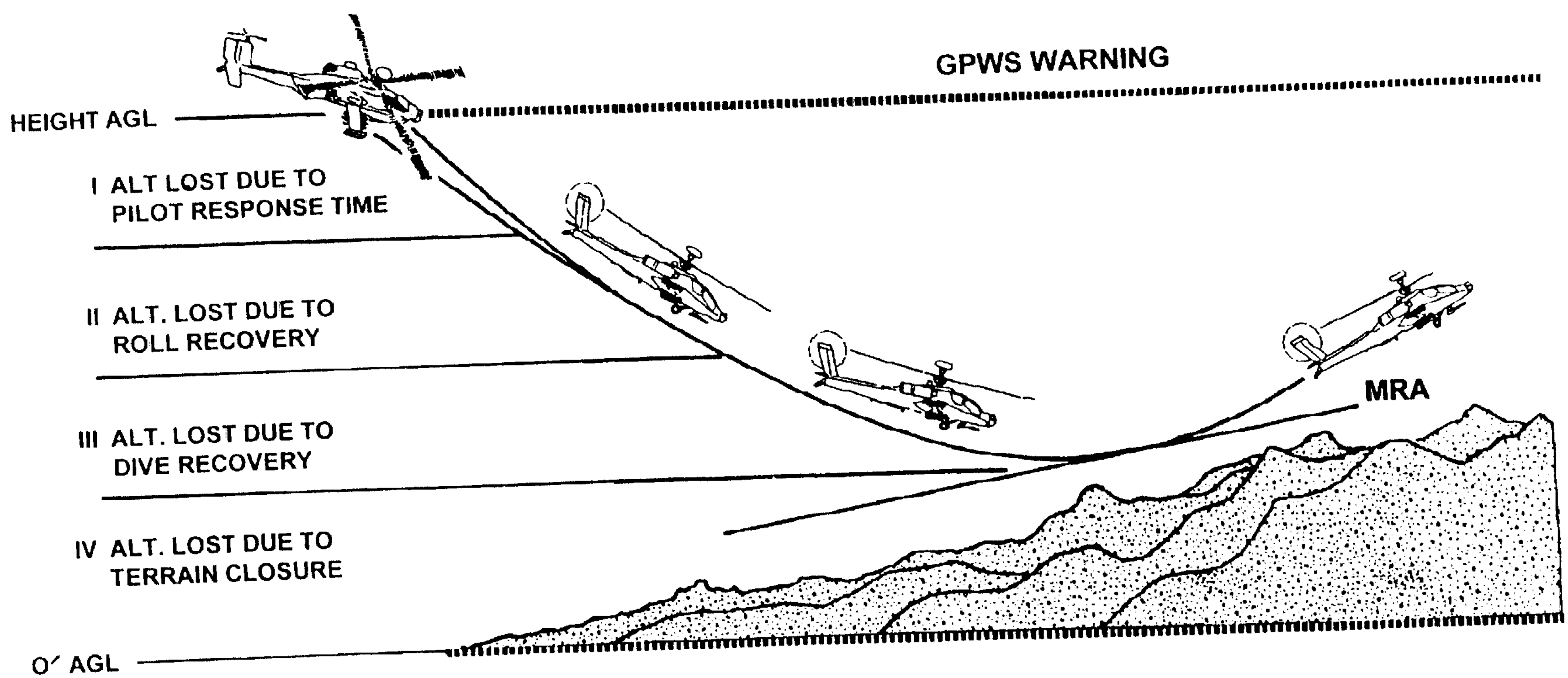
States of Protection

- Excessive Descent Rate
- Excessive Terrain Closure
- Descent Below Minimum Altitude
- Altitude Loss After Takeoff
- Descent Below ILS Glideslope
- Special: Bank Angle, Tail Strike and Gear-Up (When Landing)

PMA-209 15

CAT III KINEMATIC SOLUTION

RECOVERY ALTITUDE LOSS = I + II + III + IV



• ALL VALUES CONTINUOUSLY COMPUTED BY GPWS 10 TIMES PER SECOND

PMA-209

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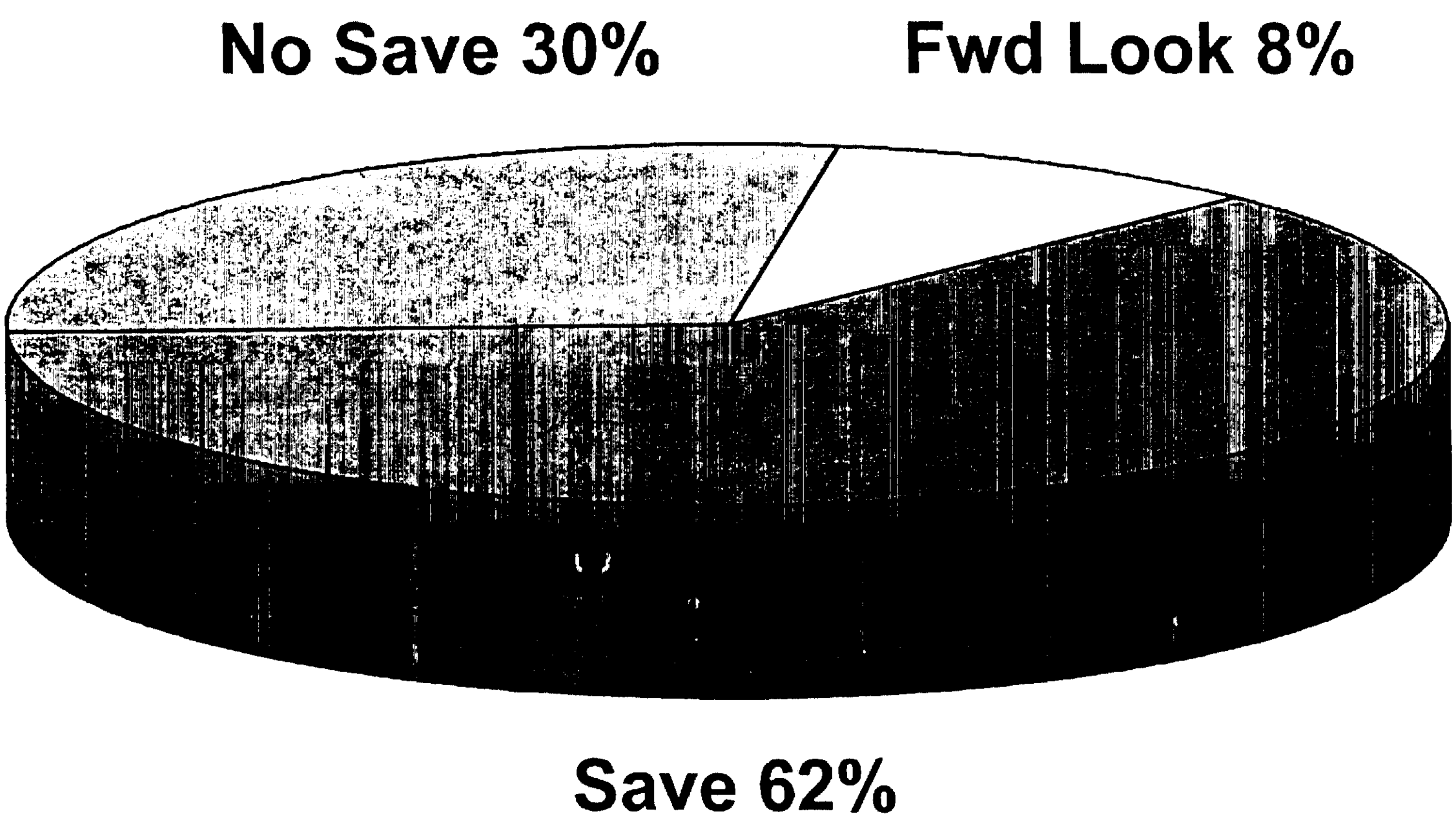
GPWS OUTPUTS

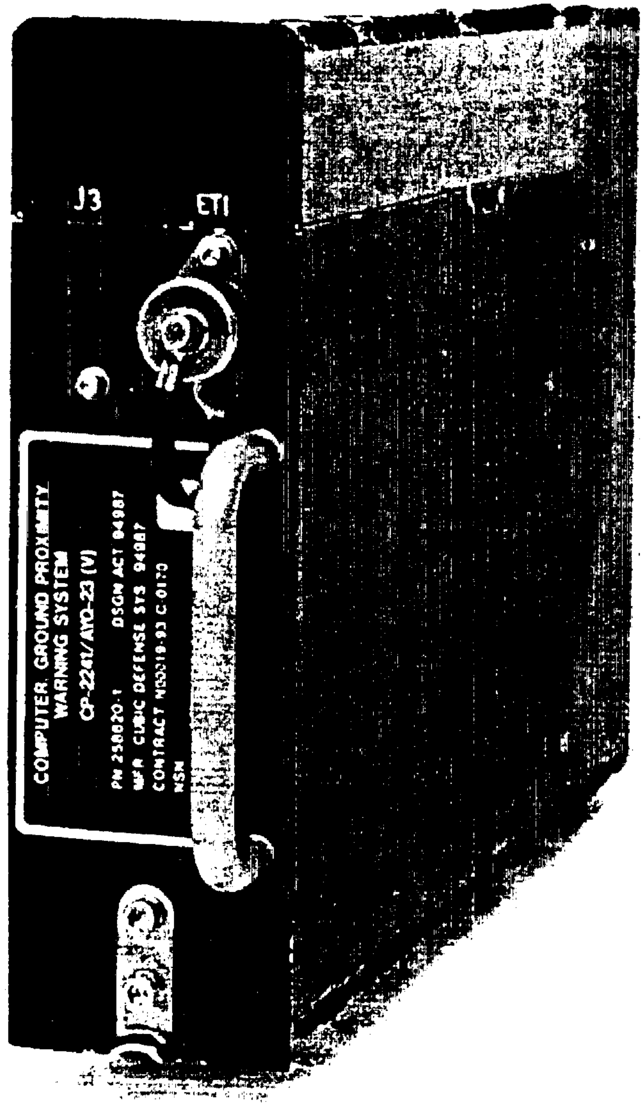
- Voice warnings
  - based on CFIT condition
- Visual warnings/advisories
  - platform specific implementation

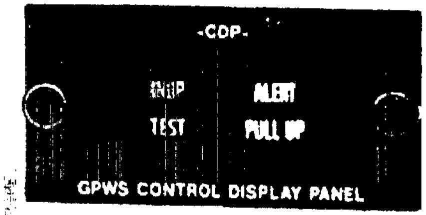
CAT III CFIT ANALYSIS*
GPWS SAVE PROBABILITY



* Based on NSC accident statistics

GPWS CAT III HARDWARE





<u>Processor Dimensions</u>
7.62 x 2.25 x 12.4 (in.)
1/4 ATR (short)

<u>Weight</u>
7.4 pounds

EMBEDDED INTEGRATION

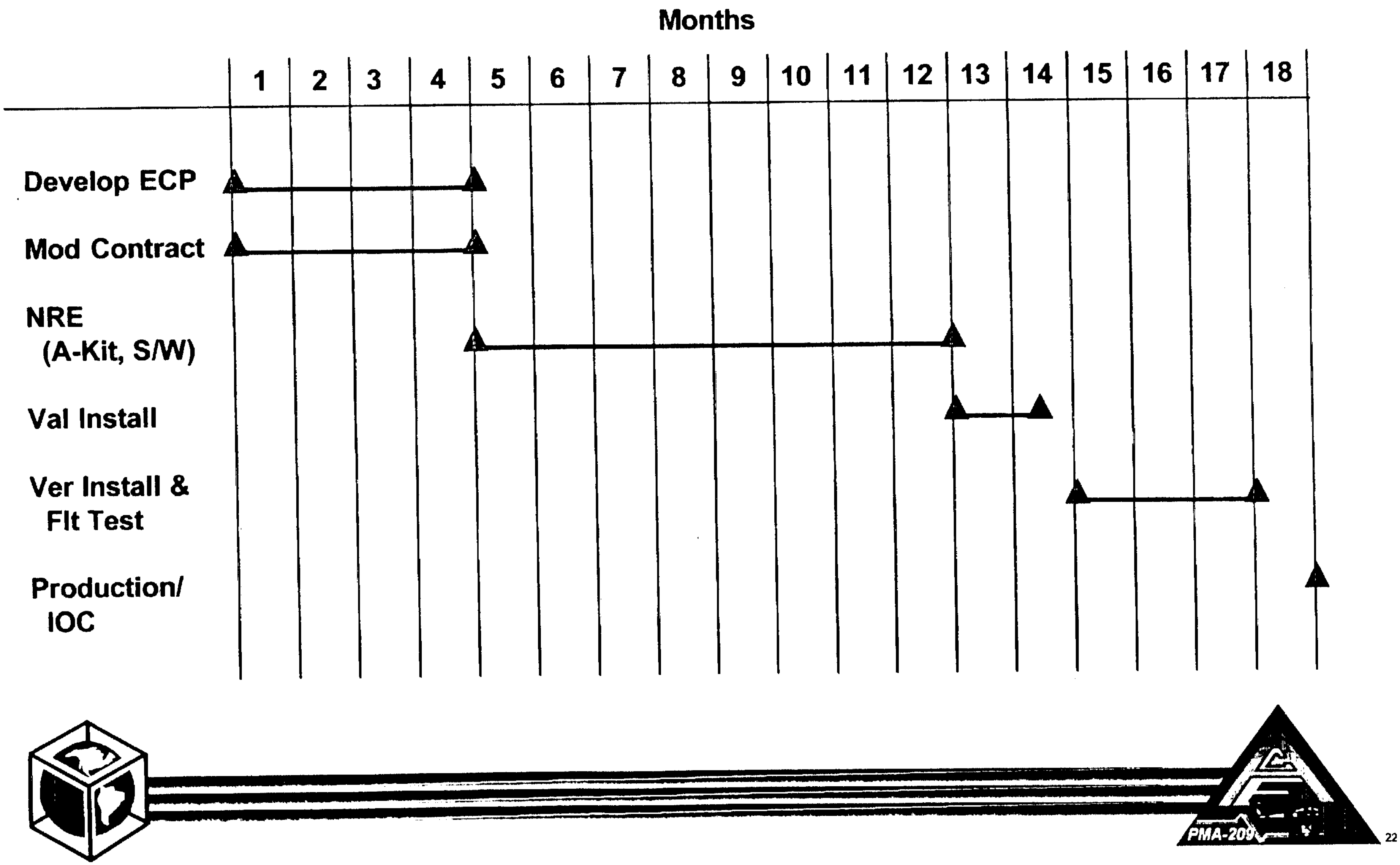
- Targeting CH-60 as lead embedded platform
- Requirements analysis and system integration planned for FY99
- Minimum host processor requirements:
  - 10 Hz data rate
  - >3 MIPS performance
  - 146 Kbytes program memory
  - 29 Kbytes RAM

FUTURE INITIATIVES

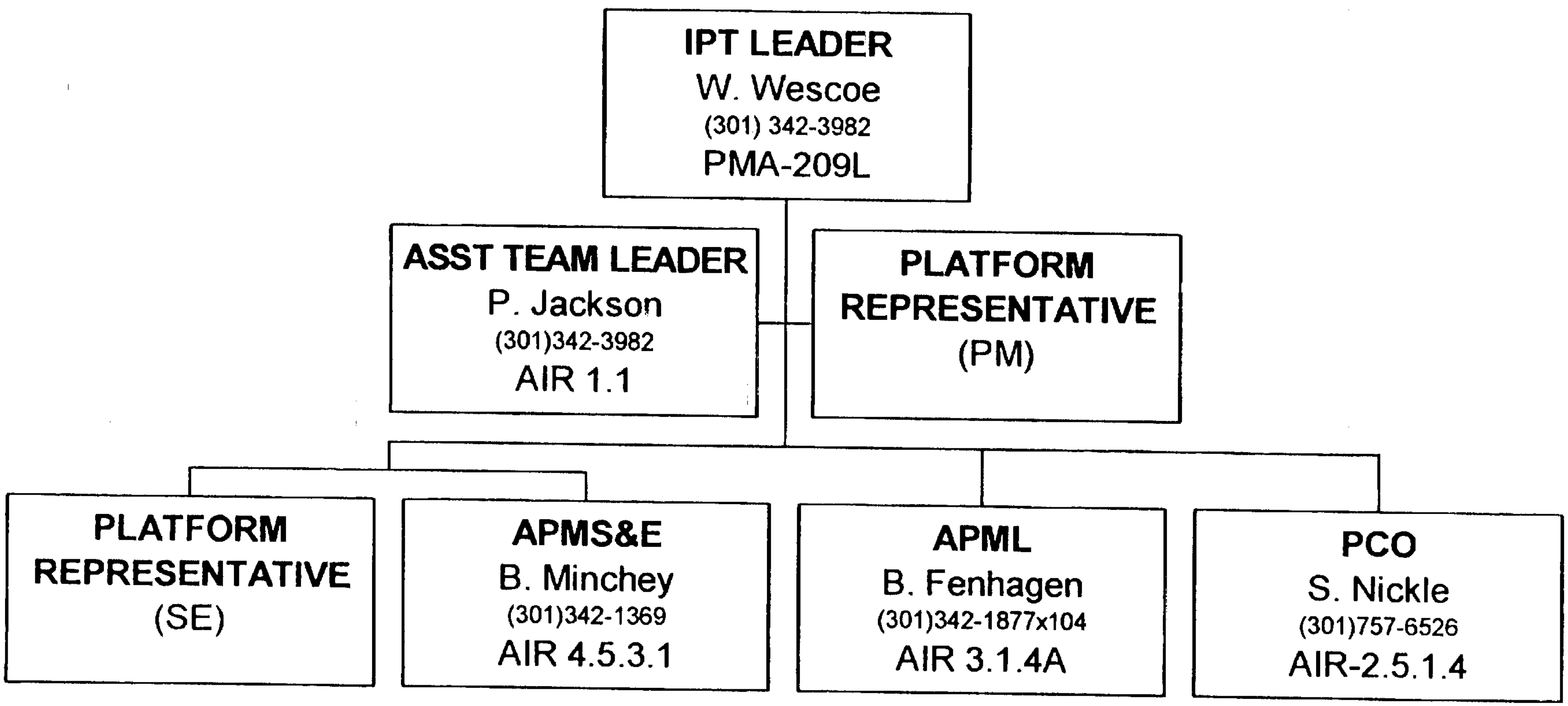
- Analyze incorporation of "*forward-look*" capability using digital terrain data (GPWS Terrain Aware)
  - Interface with Tactical Aircraft Moving Map Capability (TAMMAC) - the digital map standard for Naval aviation
  - Provide Situational Awareness displays and advisories
  - Determine user requirements and best technical solution

PMA-209 21

NOTIONAL SCHEDULE



PMA-209 SUPPORT STRUCTURE



PMA-209

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SUMMARY

- Helicopters are most susceptible to CFITs
- GPWS will provide significant safety payoff potential
- PMA-209/Cubic system approved and funded for production
- Contract vehicle and Life-cycle support in place for new users

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Speech notes only: Does not reflect NOS policy.

Single Scan

516-03

Airport Data

The Instrument Approach Procedures Branch (AC&C) charts approaches to approximately 7,500 runway ends in the United States, Puerto Rico and the Pacific Islands.

The Federal Aviation Administration (FAA) has approximately 16,000 airports in their system:

a. 1,000 airports have precision Instrument Approach Procedures (IAP).

b. 2,000 additional airports have non-precision IAPs.

c. 3,800 additional airports are open to the public and are eligible for IAPs.

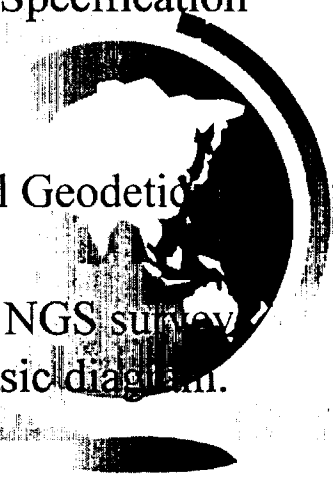
d. 10,000 remaining airports could become eligible for IAPs.

There are approximately 1,000 airports (see A above) in the Obstruction Chart (OC) program. These airports are surveyed under the provision of the FAA's Specification Number 405.

a. 650 airports have an Obstacle Data Sheet. See NGS Form 81.

b. 180 airports have the textural information in digital form on the National Geodetic Survey (NGS) web site: http://www.ngs.noaa.gov

There are approximately 2,000 airports (see B above) that are scheduled for NGS survey and the data will be available on the web site with both a textural and basic diagram. See NGS Form 292.



Minimum Safe Altitude Systems (MSAW)

- 2 mile resolution data
- Highest terrain and obstacle in each 2 mile by 2 mile bin or cell
- Advisory systems used by air traffic control personnel

ARTSII and ARTSIII Traditional Sites

- 250 now being maintained
- Maintenance cycle, 6 months (approx. 50 per month)
- Present size 62 nautical mile radius (80 nm proposed)

ARTSIIE and ARTSIIIE General Terrain Sites

- 140 ARTSIIE sites proposed (approx. 8 produced)
- 5 ARTSIIIE Common Area ARTS proposed (2 produced)
- Maintenance Cycle: 28 days (proposed)
- Present size approx.: 128nm x 128nm.
  Proposed size: 160nm x 160nm.
  ARTSIIIE: various sizes up to 200nm x 200nm.

STARS MSAW Sites

- 240 total proposed including 74 military sites
- Maintenance cycle not yet proposed
- Same size and format as ARTSIIE proposed (GTM)

Proposed Standards for Aviation Terrain and Obstacle Databases

Ronald M. Bolton, NOAA, Aeronautical Chart Division

SUMMARY

With the increase in direct routing and the advent of free flight and Global Positioning System (GPS) navigation, the aviation industry needs accurate and consistent worldwide terrain and obstacle databases to improve the safety and efficiency of all phases of flight. In support of this need, this paper proposes standards for terrain and obstacle databases to be used to compile paper and electronic aeronautical charts and for support of air traffic control.

Proposed Standards for Aviation Terrain and Obstacle Databases

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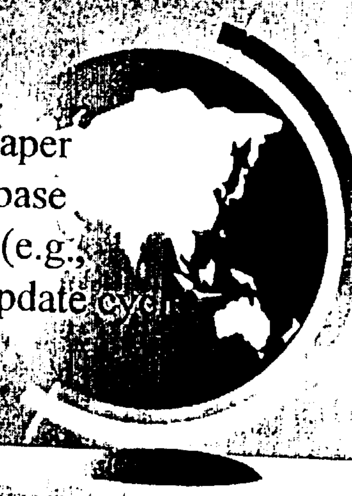
Proposed Standards for Aviation Terrain and Obstacle Databases

1. Introduction.

1.1 Air travel is one of the safest means of mass transportation; yet, the aviation accident rate has remained almost constant in recent years.[1] Controlled Flight Into Terrain (CFIT) has been a leading category of air carrier accidents.[2] Improved air traffic control system displays, advanced ground proximity warning systems, and aeronautical charts supported by current terrain and obstacle databases could enhance air travel safety worldwide.[3]

1.2 To comprehensively address terrain and obstacle database issues, this paper discusses the following: a) database resolution; b) database accuracy; c) database integrity; d) storage of database information; e) inclusion of cultural features (e.g., obstacles: bridges, towers, chimneys, etc.) with terrain features; f) database update cycle; and g) approval and certification of terrain and obstacle databases.



Proposed Standards for Aviation Terrain and Obstacle Databases

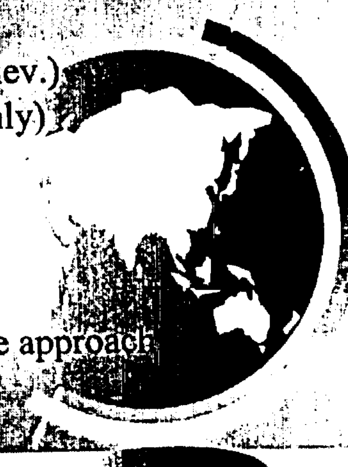
2. <u>Discussion.</u>

2.1 **Terrain and Obstacle Database Resolution** - Computer systems supporting flight in enroute, terminal area transitions, initial approach segments, and final approach segments have different database resolution requirements. Therefore, it is critically important, for safety and flight efficiency, to define appropriate data density for databases used to navigate or control air traffic in these phases of flight. Since the resolution of any terrain and obstacle database will be finite, and because the terrain avoidance capability of a flight management system is directly related to the spacing of terrain and obstacles in its database, several different data spacings will be required if the database is remain cost effective and functional. Table 1 presents a recommendation for terrain and obstacle data spacings in aviation databases supporting the above phases of flight:

Table 1

Phase of Flight	**Resolution (Arc Distance)**
Enroute (50nm or more from terminal)*	15'X 15' (with high and low elev.)
Terminal area transitions (6-50nm)*	15" X 15" (high elev. only)
Initial approach segment (6nm to FAF)*	6" X 6" (high elev. only)
Final approach segment (FAF to 1nm** from runway)	3" X 3" (high elev. in TERPS Trapezoid only)

*Highest obstacle in resolution cell should be considered in computing highest value.
**At 1nm from runway, specially inserted approach-specific data should be used for the approach



Proposed Standards for Aviation Terrain and Obstacle Databases

2.2 **Database Accuracy** - Throughout the world, different geodetic survey, cartographic, and photogrammetric sources exist for terrain information. Data differences among various sources of terrain information could lead to inconsistencies in the performance of terrain avoidance systems using terrain information from multiple sources. Therefore, a set of standards for data collected to construct databases for the above phases of flight (Table 1) is required, so that high quality and consistent terrain and obstacle data are available to all ICAO member states. Table 2 presents a recommended standard for terrain and obstacle data collection:

Table 2

Phase of Flight	**Absolute Accuracy (Meters)**	
	Horizontal	**Vertical**
Enroute (50nm or more from terminal)	150	50
Terminal area transition (50-100nm)	50	30
Initial approach segment (10nm to FAF)	50	30
Final approach segment (FAF to 1nm** from runway)	15†	20†

**At 1nm from runway, specially inserted approach-specific data should be used that comply with ICAO Annex 4, Section 4.8.[6]

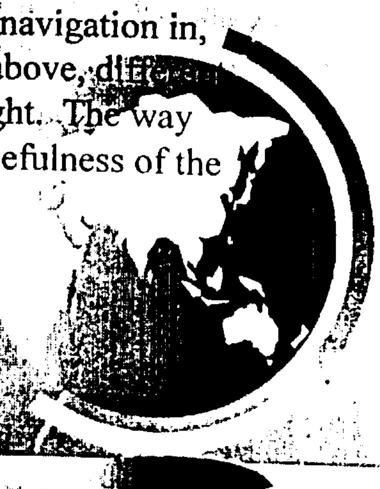
†TERPS Trapezoid only

Proposed Standards for Aviation Terrain and Obstacle Databases

2.3 **Database Integrity** - As described above, there are different sources for terrain information worldwide. Not only do many ICAO member states have databases containing terrain data, but member states might use a variety of maps, charts, survey data, and photogrammetric data to create their terrain and obstacle databases. To assure database integrity, the data should be collected according to established standards, such as those presented in paragraphs 2.1 and 2.2 above. In addition, samples of collected and verified data sets should be field-checked using GPS according to precise positioning system (PPS) standards (in the WGS-84 Datum). After careful review, ICAO member states should share their terrain data sets with other member states.

Proposed Standards for Aviation Terrain and Obstacle Databases

2.4 **Storage of Database Information** - Computer disks now provide sufficient (multi-gigabyte) capacity to store the volume of data necessary to fully support terrain and obstacle avoidance alerting systems and graphic display systems. The storage methodology requires study. Any ICAO task group dedicated to such a study should consult with the aviation industry to set international standards for terrain and obstacle data storage. The following data storage topics should be considered in the study: storage formats; storage media; retrieval algorithms; and the impact of compression and decompression algorithms on speed of retrieval for depiction and alerting operations. Since multiple database resolutions and accuracies will be used to support navigation in, and air traffic control of, the various phases of flight described in sections 2.1 and 2.2 above, different subsets of the database must be accessed operationally as a function of the phase of flight. The way terrain and obstacle information is accessed and retrieved will determine the relative usefulness of the alerting and display systems.[4]



Proposed Standards for Aviation Terrain and Obstacle Databases

2.5 **Inclusion of Cultural Features in the Database** - The databases for aviation navigation and display systems could include both geographic data for naturally occurring terrain features, as well as cultural features (e.g., obstacles: bridges, towers, chimneys, etc.). Admittedly, the inclusion of cultural features will force frequent updates and will be costly; however, cultural features must be included to provide comprehensive support for terrain and obstacle alerting systems and navigation display systems--especially for off-route flights.[5] Of course selective methodology must be applied, since many obstacles will not present a hazard. Therefore, the choice of which obstacles to include in the database will affect the cost, volume, and safety value of stored data. Many chart producers portray Maximum Elevation Figures on Visual Flight Rule charts that include cultural features along with terrain features. They also depict Off Route Obstruction Clearance Altitudes on Low Altitude Enroute Charts and Area Navigation Charts for Instrument Flight Rule (IFR) navigation that include obstacles and buffers. The accuracy of available cultural feature data will vary. However, for most alerting and display systems, Table 3 presents recommended accuracy standards for cultural features included in aviation databases as a function of the phase of flight.

Table 3

Phase of Flight	**Accuracy**	
	Horizontal	**Vertical**
Enroute (50nm or more from terminal)	50	50
Terminal area transition (50 - 100nm)	50	30
Initial approach segment (10nm to FAF)	50	30
Final approach segment* (FAF to 1nm from runway)	15†	10†

*At 1nm from the runway, specially inserted approach-specific data should be used that comply with IC Annex 4, Section 4.8.[6]
†TERPS Trapezoid only

Proposed Standards for Aviation Terrain and Obstacle Databases

2.6 **Updating the Terrain and Obstacle Database** - Frequent changes to cultural features will require updates to the database. It is recommended that the 56-day IFR charting update cycle be used to update databases supporting air navigation and traffic control.

2.7 **Certification and Approval of Terrain and Obstacle Databases** - Many databases currently supporting aircraft navigation (e.g., Flight Management Systems, moving map systems, etc.) are not certified by ICAO, and there is no clear guidance to do so. ICAO member states should be involved with certification of aviation terrain and obstacle databases, either by collectively verifying and approving data over sovereign territory or by contracting to have data verified to the extent possible. Aviation safety justifies such reviews.

SINGLE SCAN

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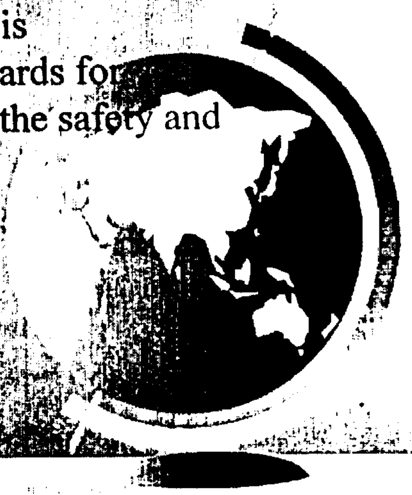
Proposed Standards for Aviation Terrain and Obstacle Databases

2.8 **General Considerations** - Creation and maintenance of terrain and obstacle databases will be costly and time consuming. But doing so will give pilots and air traffic controllers advance warnings of Controlled Flight Toward Terrain and potential CFIT. "For the first time, pilots will see a moving picture of what's in front of them on a cockpit screen, helping them to stay away from obstacles they can't see because of darkness or weather."[5] The terrain database also will support advanced ground proximity warning systems coupled to GPS.

3.0 <u>Recommendation.</u>

3.1 Given the growing practices of direct routing and free flight using GPS, it is recommended that an ICAO task group be formed immediately to develop standards for aviation terrain and obstacle databases. Such standards ultimately will improve the safety and efficiency of air travel worldwide.



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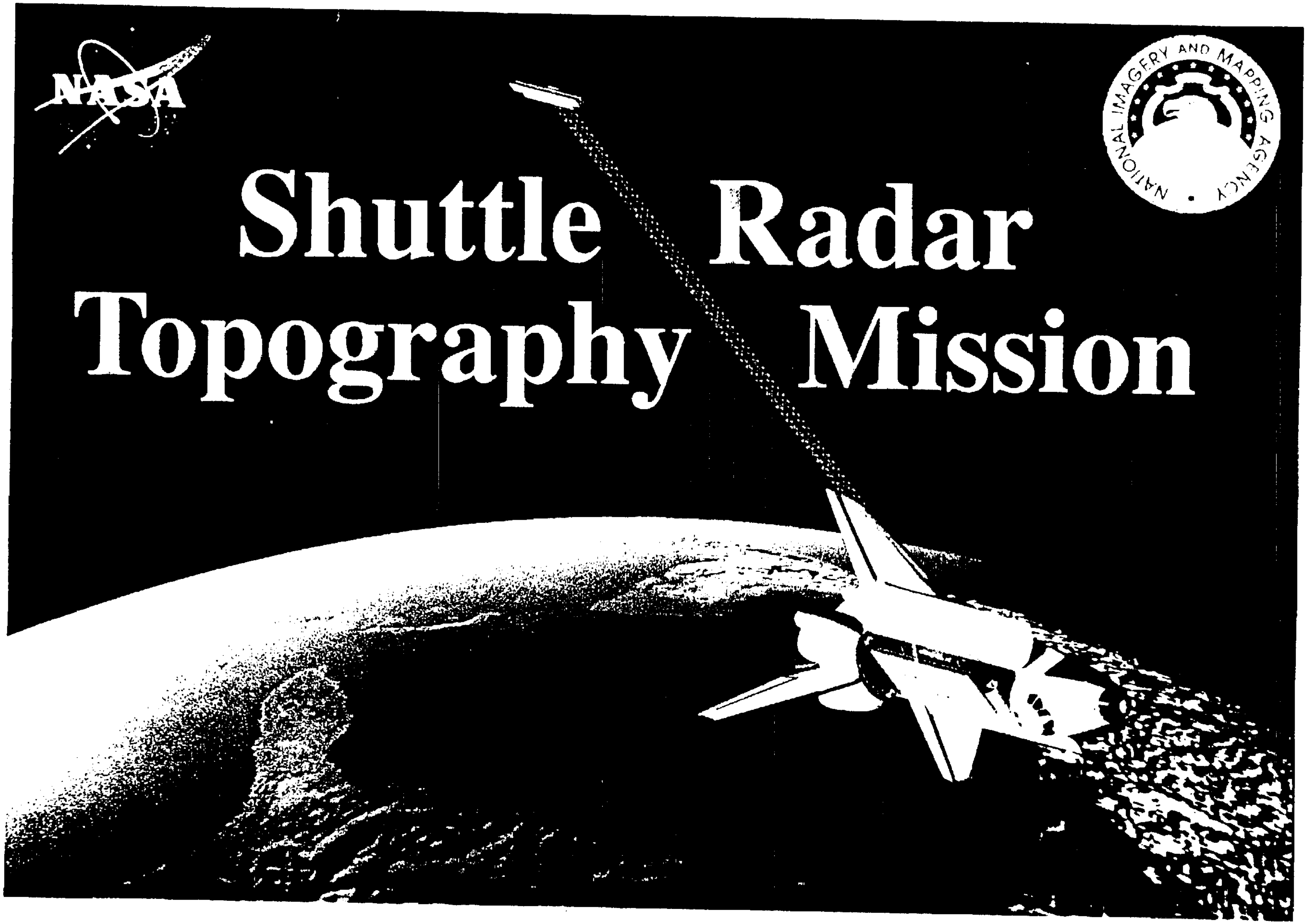
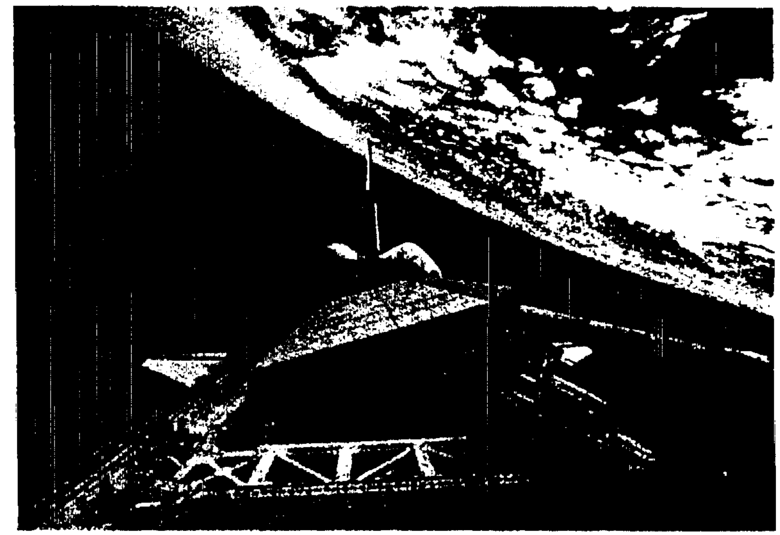


NASA
NATIONAL IMAGERY AND MAPPING AGENCY
Shuttle Radar Topography Mission

JPL

Shuttle Radar Topography Mission

Background



Space Radar Laboratory

- SRL consisted of
  - Spaceborne Imaging Radar-C (SIR-C), a multipolarimetric, dual frequency imaging radar with phased array antennas
  - X-band Synthetic Aperture Radar, German/Italian X-band single polarization imaging radar with articulating antenna
- 52 PI teams from 13 nations, experiments in Geology, Oceanography, Hydrology, Ecology, Interferometry
- Two flights in '94 (STS-59, -68) achieved 100% of science objectives, demonstrated interferometry for topographic mapping

Shuttle Radar Topography Mission

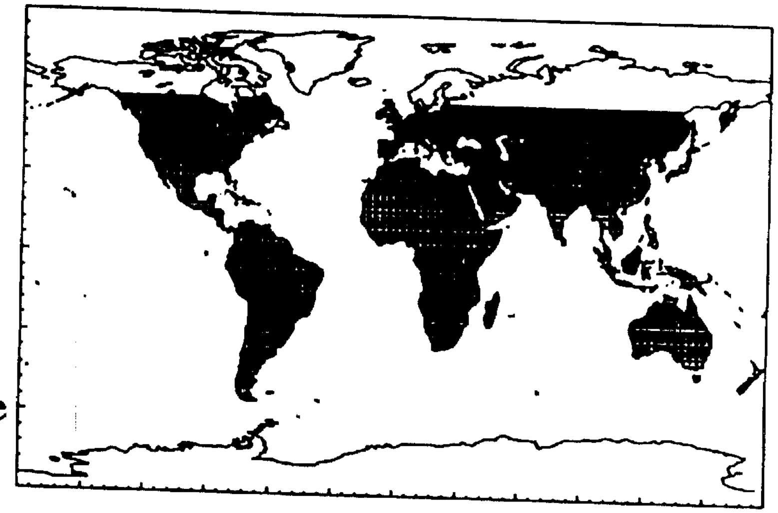
- Reflight of SRL hardware with modifications to form fixed-baseline SAR interferometer
- Sponsored jointly by NASA and DoD's National Imagery and Mapping Agency
- Objective is near-global digital topographic and image maps with 30 meter resolution, data set delivered by 2000
- Manifested on STS-101, Sept., '99

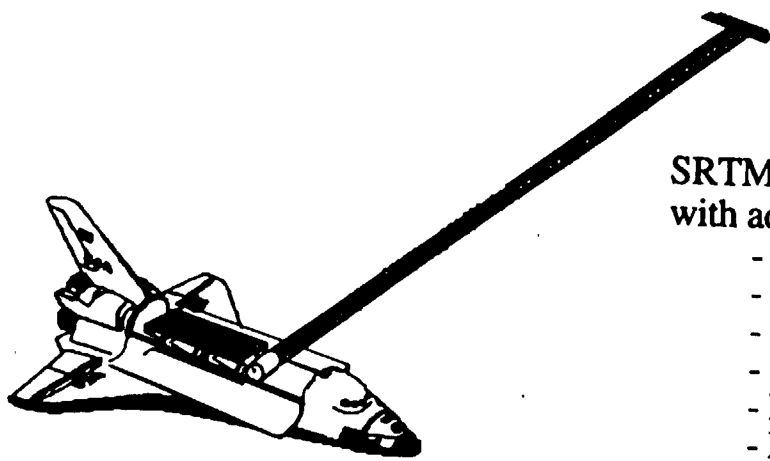
JPL

Shuttle Radar Topography Mission

During a single 11-day Space Shuttle flight SRTM will produce:

- A digital topographic map of 80% of Earth land surface (everything between ±60° latitude) with:
  - 30 horizontal resolution
  - 8-10 meters relative height resolution
  - Globally consistent characteristics and datum
- Rectified, terrain-corrected mosaicable C-band image strips for 80% of land surface at 30 meter resolution

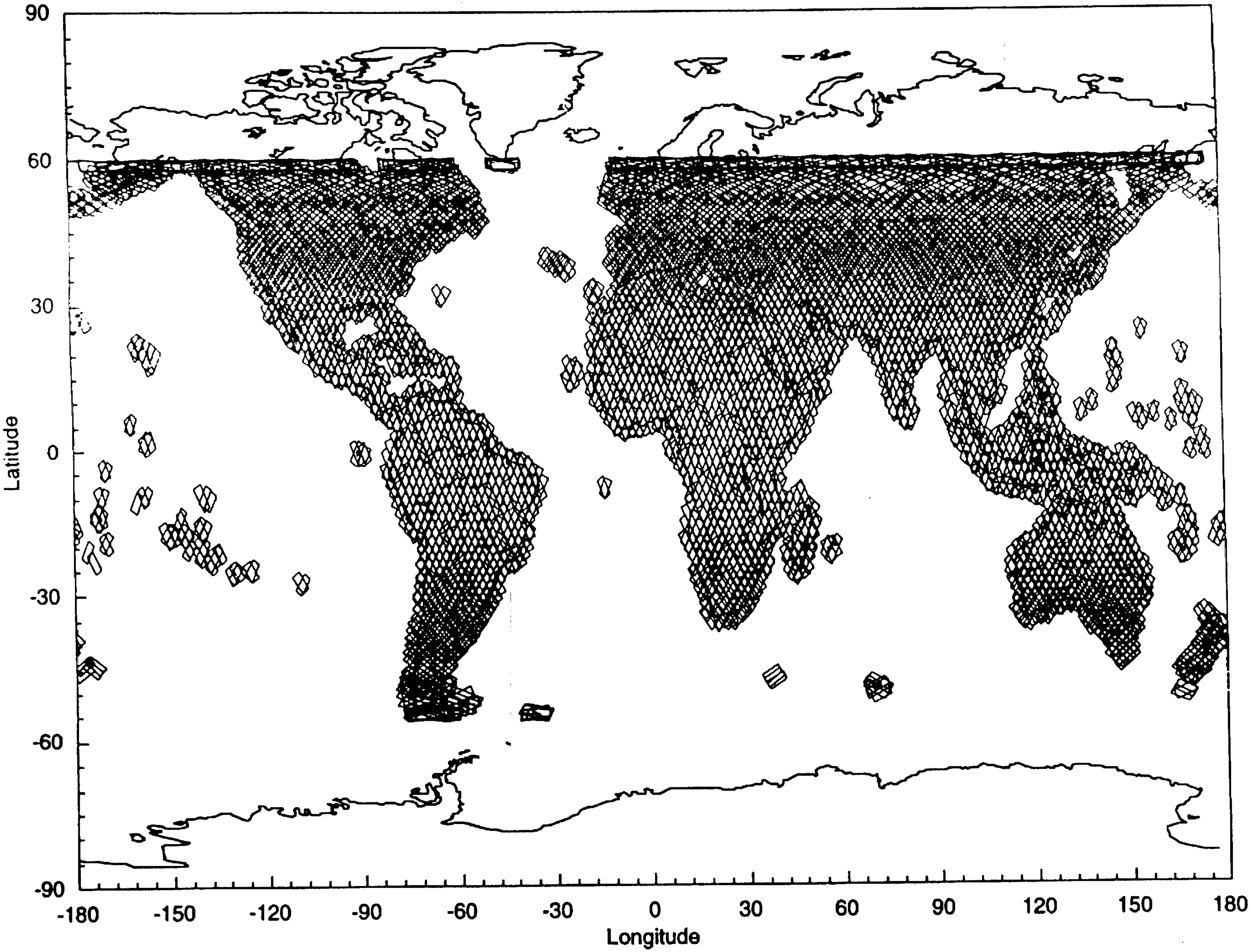




SRTM will consist of the SIR-C and X-SAR instruments with addition of:

- 60 meter Space Station-derived mast
- Additional C-band and X-band antennae
- Optical alignment device inherited from ASTRO-1,2
- Star tracker derived from Pluto star tracker or from DoD
- Laser gyro inherited from ASTRO-1,2
- Redundant GPS receivers

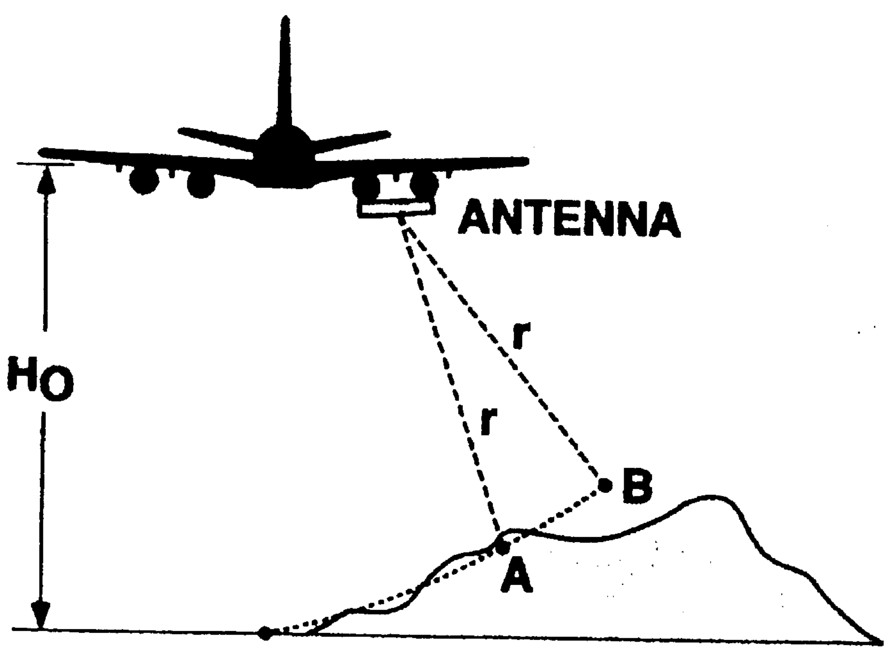
233.1 km, 57°, 159 orbits, 225 km swaths



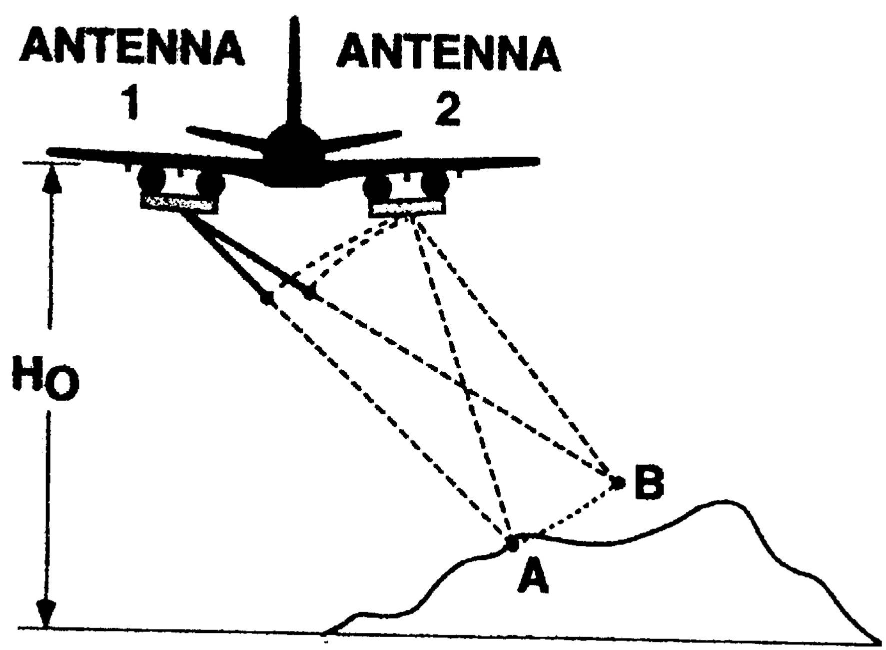
ADVANCED RADAR TECHNIQUES AT JPL

PRINCIPLE OF INTERFEROMETRIC SAR

CONVENTIONAL SAR



INTERFEROMETRIC SAR (IFSAR)

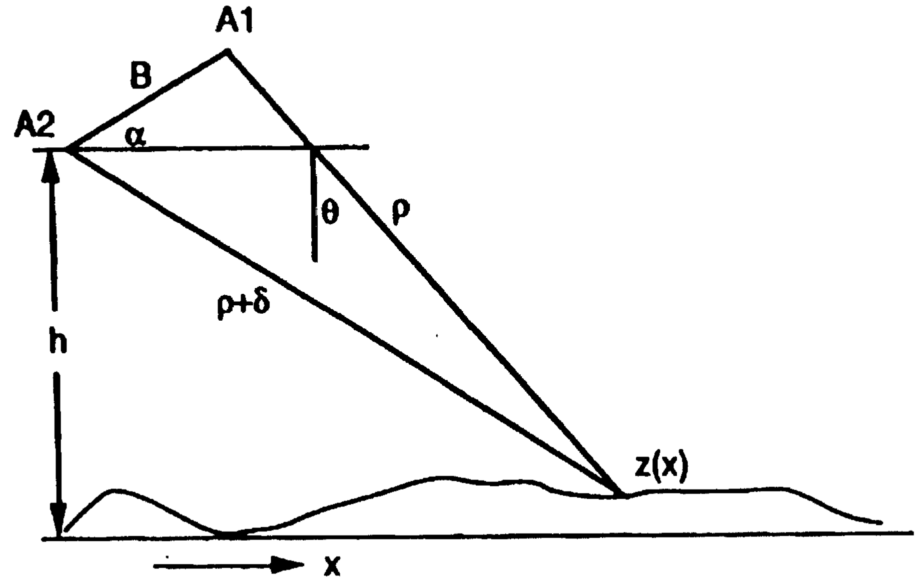


RADAR INTERFEROMETRY

THEORY OF SPATIAL BASELINE CONFIGURATIONS

DEFINING GEOMETRY AND PARAMETERS:

SURFACE TOPOGRAPHY	$z(x)$
AIRCRAFT ALTITUDE	h
BASELINE DISTANCE	B
SLANT RANGE	ρ
LOOK ANGLE	θ
BASELINE ANGLE	α
PATH LENGTH DIFFERENCE	δ



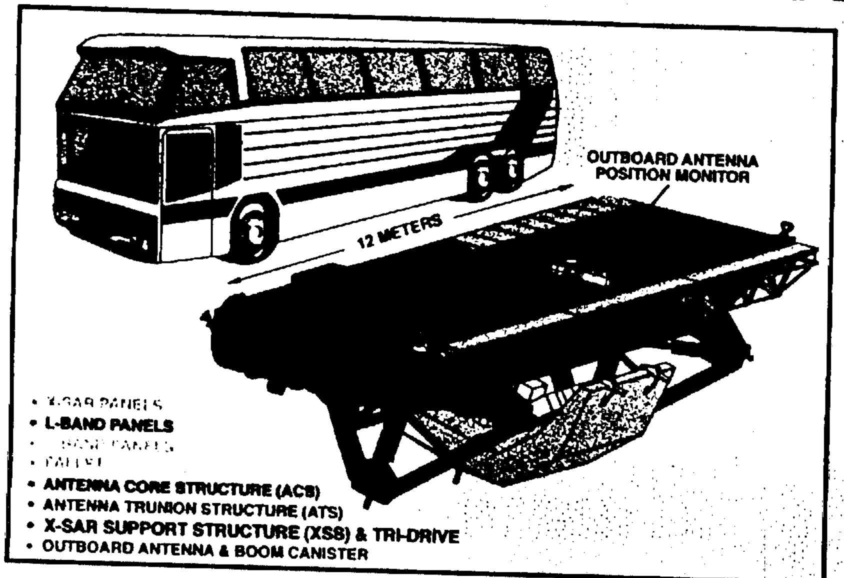
RESULTING EQUATIONS FOR MEASURED PHASE ϕ, WAVELENGTH λ

$$\delta = \phi\lambda/2\pi \quad (1)$$

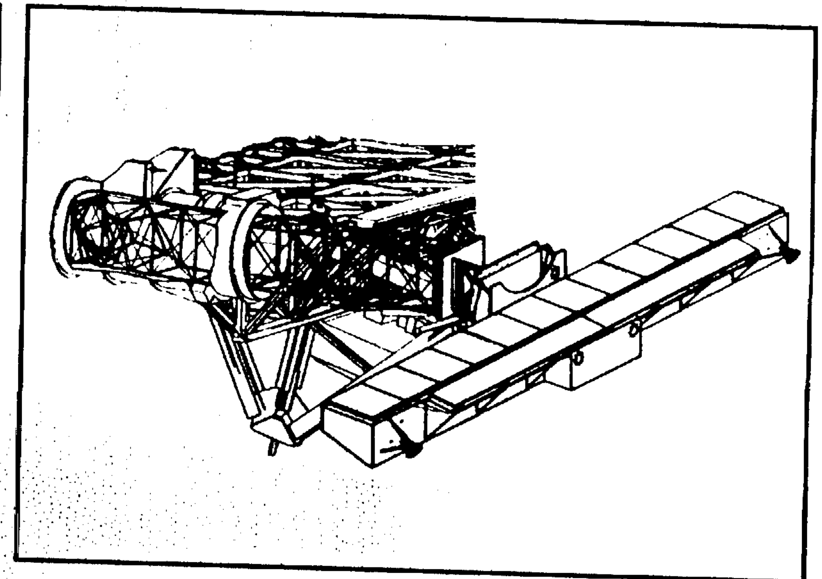
$$\sin(\alpha-\theta) = ((\rho+\delta)**2 - \rho**2 - B**2)/(2*\rho*B) \quad (2)$$

$$z(x) = h - \rho\cos(\alpha)\cos(\alpha-\theta) + \rho\sin(\alpha)\sin(\alpha-\theta) \quad (3)$$

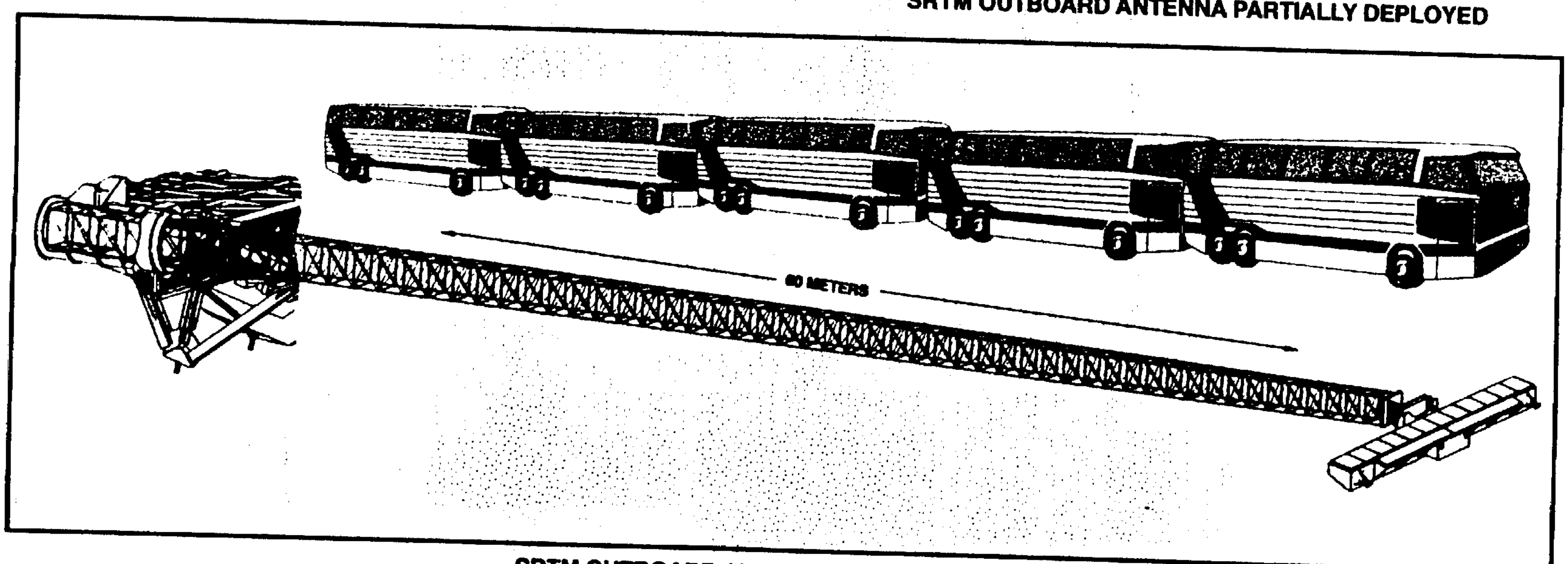
SRTM HARDWARE



SRTM OUTBOARD ANTENNA STOWED



SRTM OUTBOARD ANTENNA PARTIALLY DEPLOYED



SRTM OUTBOARD ANTENNA FULLY DEPLOYED

FUTURE TOPOGRAPHIC RADAR MISSION WILL MAP 80% OF THE EARTH

A Space Shuttle mission scheduled to be flown in May 2000 will carry a specially modified radar system that will produce the most accurate and complete topographic map of Earth's surface ever assembled.

The planned 11-day mission, called the Shuttle Radar Topography Mission (SRTM), is a cooperative project between NASA and the Defense Mapping Agency of the U.S. Department of Defense. A formal memorandum of understanding to develop and conduct the mission was finalized on July 8.

The mission is designed to collect three-dimensional measurements of nearly 80 percent of the Earth's land surface, except near the poles, with an accuracy of better than 16 meters (53 feet). The regions to be mapped are home to about 95 percent of the world's population.

SRTM will use the same radar instrument that comprised the SpaceborneImaging Radar-C (SIR-C) that flew twice on Space Shuttle Endeavour in 1994. To collect the topographic images, engineers will add an almost 60-meter-long (200-foot) mast, additional C-band imaging antennas, and improved tracking and navigation devices.

The mast, which was developed using the design for the truss structure of the International Space Station, will extend sideways from the orbiter's cargo bay. The antennae at the tip will allow the system to acquire stereo-like radar images of Earth's surface through a technique called interferometry. Such space-based interferometry was successfully tested during SIR-C's second flight.

Scientists will then use the 3-D images to generate computer versions of topographic maps, called digital elevation models, that can be used for a large number of scientific, civilian and military applications.

"Excepting measurements from weather satellites, the topographic informationproduced from this mission will be the most universally useful data set about Earth that NASA has ever produced," according to NASA Program Scientist Dr. Miriam Baltuck. "Possible applications range from scientific uses such as planetary geophysics or hydrologic drainage system modeling, to more realistic flight simulators for military aircraft, to commercial uses like better locations for cellular phone towers and improved maps for backpackers."

Traditionally, topographic maps have been generated from stereo pairs of photographs acquired from high-altitude aircraft and satellites. However, such optical systems cannot penetrate the cloud cover that blankets nearly 40 percent of the Earth's surface. In some tropical regions the cloud cover is virtually continuous and, as a result, significant portions of Earthís surface have never been mapped in detail.

"We have a better global map of Venus than we do for the Earth," said Dr. Michael Kobrick, co-originator of the SRTM mission concept at NASA's Jet Propulsion Laboratory. "Since radars can see right through clouds, SRTM's 11-day flight will give us enough data to produce an image of the Earth 30 times more precise than any that currently exist -- and the best part is that the image will be in 3-D."

The Defense Mapping Agency (DMA), Fairfax, VA, plans to use the radardata to fulfill a joint defense requirement for a digital global terrain elevation map with data points spaced approximately every 30 meters (100 feet). The DMA currently holds a digital terrain map over 65 percent of the Earth's land mass with data points every 100 meters (330 feet). Completion of this data set has been hampered by a lack of cloud-free photos over major portions of the world.

The SRTM mission will be implemented by the Jet Propulsion Laboratory for NASA's Office of Mission to Planet Earth, Washington, DC.

7/15/96 MAH

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PUBLIC INFORMATION OFFICE
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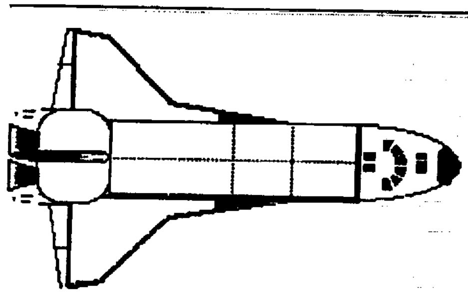
July 15, 1996

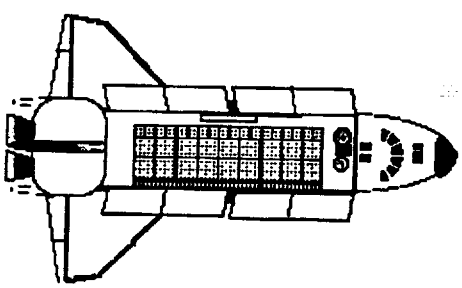
What is SIR-C/X-SAR?

SIR-C/X-SAR stands for Spaceborne Imaging Radar-C/X-band Synthetic Aperture Radar. SIR-C/X-SAR is an imaging radar system scheduled for launch aboard the NASA Space Shuttle in 1994. It consists of a radar antenna structure and associated radar system hardware that is designed to fit inside the Space Shuttle's cargo bay. On take-off, the cargo bay doors are closed as seen in the graphic on the next page. After the Space Shuttle has reached a stable Earth orbit, the cargo bay doors will be opened , the antenna structure will be deployed, and SIR-C/X-SAR will be switched on, to begin using its state-of-the-art radar technology to image the earth's surface. Radar images generated by SIR-C/X-SAR will be used by scientists to help understand some of the processes which affect the earth's environment, such as deforestation in the Amazon, desertification south of the Sahara, and soil moisture retention in the Mid-West.

Deploying SIR-C



Space Shuttle doors closed



Space Shuttle doors open, showing SIR-C/X-SAR antenna

The SIR-C/X-SAR Project

SIR-C/X-SAR is a joint project of the National Aeronautics and Space Administration (NASA), the German Space Agency (DARA) and the Italian Space Agency (ASI). It is the next step in a series of spaceborne imaging radars, beginning with SEASAT in 1978, continuing with SIR-A (1981), Germany's Microwave Remote Sensing Experiment (1983), and SIR-B (1984). It is a precursor to the Earth Observing System (EOS) imaging radar system planned for the end of the decade.

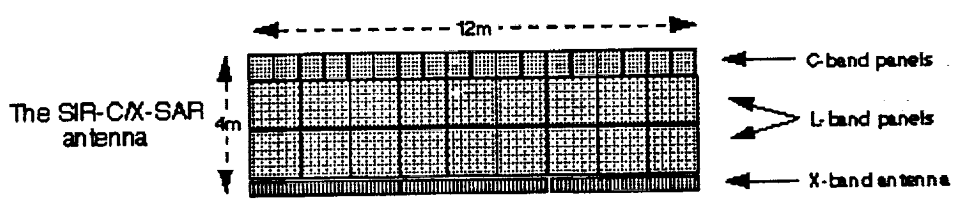
Science Objectives

SIR-C/X-SAR's unique contributions to Earth observation and monitoring are its capability to measure, from space, the radar signature of the surface at three different wavelengths, and to make measurements for different polarizations at two of those wavelengths. SIR-C image data will help scientists understand the physics behind some of the phenomena seen in radar images at just one wavelength/polarization, such as those produced by SEASAT. Investigators on the SIR-C/X-SAR Science team will use the radar image data from SIR-C/X-SAR to make measurements of the following:

- Vegetation type, extent and deforestation
- Soil moisture content
- Ocean dynamics, wave and surface wind speeds and directions
- Volcanism and tectonic activity
- Soil erosion and desertification

SIR-C/X-SAR Instrument Description

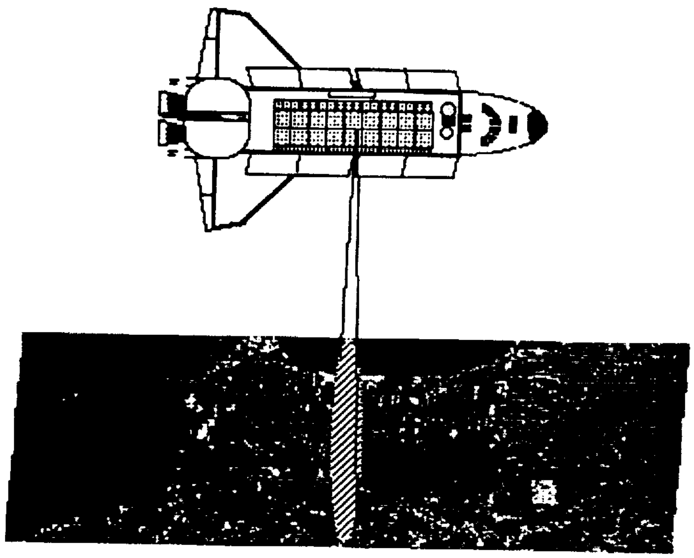
The SIR-C/X-SAR antenna structure actually consists of three individual antennas, one operating at L-band (23.5cm wavelength), one at C-band (5.8cm wavelength) and the third at X-band (3cm wavelength). The L-band and C-band antennas are constructed from separate panels that can measure both horizontal and vertical polarizations.



The SIR-C/X-SAR antenna is the most massive piece of hardware (at a total of 10,500 kilograms) ever assembled at the Jet Propulsion Laboratory, and measures 12 meters by 4 meters. The SIR-C instrument was built by JPL and the Ball Communication Systems Division for NASA and provides the L-band and C-band measurements at different polarizations. The L-band and C-band antennas employ phased array technology, which allows the antenna beam pointing to be adjusted electronically. The X-SAR instrument is built by the Dornier and Alenia Spazio companies for DARA and ASI and operates at a single frequency, X-band. The X-SAR antenna is a slotted waveguide type, which uses a mechanical tilt to change the beam pointing direction.

SIR-C/X-SAR Image Data

During a week-long Shuttle flight, SIR-C/X-SAR will image an area of roughly 50 million square kilometers of the Earth's surface. This corresponds to a total of 50 hours of data. The peak data rate will be 225 megabits (or 225,000,000 bits) per second. The data collected will be processed into images with resolution selectable from 10 to 200 meters. The width of the area mapped out by the radar will vary from 15 to 90 kilometers, depending on how the radar is operated, and the direction in which the antenna beams are pointing. Data from SIR-C/X-SAR will be used to develop automatic techniques for extracting information from radar image data, in preparation for the EOS SAR mission later in the decade.



This schematic diagram shows the SIR-C/X-SAR antennas illuminating an area on the ground, and mapping out a swath as the Shuttle moves forward. The area shown is a SEASAT image of Los Angeles, California. North is to the right of the image shown.

More About SIR-C/X-SAR

The Shuttle Imaging Radar-C and X-Band Synthetic Aperture Radar (SIR-C/X-SAR) is a cooperative space shuttle experiment between the National Aeronautics and Space Administration (NASA), the German Space Agency (DARA), and the Italian Space Agency (ASI). The experiment is the next step forward in NASA's Spaceborne Imaging Radar (SIR) program that began with the Seasat Synthetic Aperture Radar (SAR) in 1978, and continued with SIR-A in 1981 and SIR-B in 1984. The program will eventually lead to TOPSAT, a mission to measure topography globally, and the Earth Observing System (EOS) SAR later in this decade. The program also benefits from experience gained with the Magellan Mission to Venus, other international spaceborne radar programs (e.g. ERS-1, JERS-1), and prototype aircraft sensors such as the JPL Airborne SAR (AIRSAR).

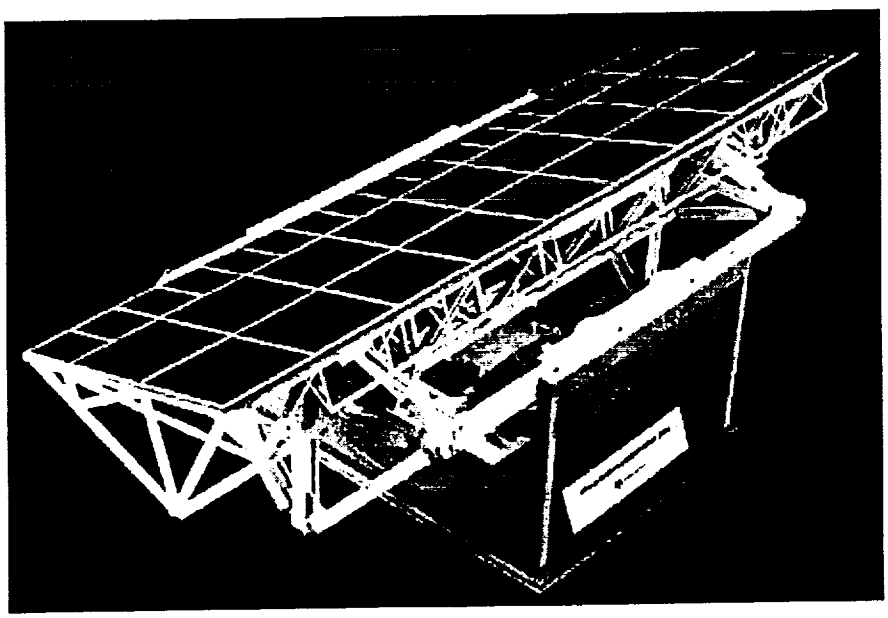
SIR-C will provide increased capability over SEASAT, SIR-A, and SIR-B by acquiring digital images simultaneously at two microwave wavelengths ([[lambda]]): L- band ([[lambda]] = 23.5 cm) and C-band ([[lambda]] = 5.8 cm). These vertically- and horizontally-polarized transmitted waves will be received on two separate channels, so that SIR-C will provide images of the magnitude of radar backscatter for four polarization combinations: HH (Horizontally-transmitted, Horizontally-received), VV (Vertically-transmitted, Vertically-received), HV, and VH; and also data on the relative phase difference between the HH, VV, VH, and HV returns. This allows derivation of the complete scattering matrix of a scene on a pixel by pixel basis. From this scattering matrix, every polarization configuration (linear, circular or elliptical) can be generated during ground processing. The radar polarimetric data will yield more detailed information about the surface geometric structure, vegetation cover, and subsurface discontinuities than image brightness alone.

Germany's imaging radar program started with the Microwave Remote Sensing Experiment (MRSE) flown aboard the Shuttle. This X-band radar was flown on the first SPACELAB mission in 1983. The program was continued by development of the X-SAR, for which cooperation with Italy was initiated. X-SAR, will operate at X-band ([[lambda]] = 3.1 cm) with VV polarization, resulting in a three-frequency capability for the total SIR-C/X-SAR system. Because radar backscatter is most strongly influenced by objects comparable in size to the radar wavelength, this multi-frequency capability will provide information about the Earth's surface over a wide range of scales not discernible with previous single-wavelength experiments.

SIR-C/X-SAR Instrumentation

SIR-C will provide multi-frequency, multi-polarization radar data. The SIR-C instrument is composed of several subsystems: the antenna array, the transmitter, the receivers, the data-handling subsystem, and the ground SAR processor. The antenna is composed of two planar arrays, one for L-band and one for C-band. Each array is composed of a uniform grid of dual-polarized microstrip antenna radiators, with each polarization port fed by a separate corporate feed network. The overall size of the SIR-C antenna is 12.0 x 3.7 meters and consists of three leaves each divided into four subpanels.

Model of the SIR-C/X-SAR antenna



Unlike previous SIR missions, the SIR-C radar beam is formed from hundreds of small low power solid state transmitters embedded in the surface of the radar antenna. By properly phasing the energy from these transmitters, the beam can be electronically steered in the range direction +/-23deg. from the nominal 40deg. off nadir position without physically moving the large radar antenna. This feature will enable images to be acquired over a wide range of incidence angles.

X-SAR will provide VV polarization images using a passive slotted waveguide antenna measuring 12.0 x 0.4 meters. Other X-SAR components include a traveling wave tube as transmitter, an exciter, receiver, and data handling subsystem. A mechanical tilt mechanism will point the X-SAR antenna to angles between 15 and 60deg., in the same direction as the L-band and C-band beams.

Both SIR-C and X-SAR can be operated as either stand alone radars or together. Roll and yaw maneuvers of the shuttle will allow data to be acquired on either side of the shuttle nadir (ground) track. The width of the imaged swath on the ground varies from 15 to 90 kilometers (9 to 56 miles) depending on the orientation of the antenna beams and the operational mode. Table 1 presents a summary of the SIR-C/X-SAR system characteristics.

Table 1: SIR-C/X-SAR System Characteristics

PARAMETER	L-BAND	C-BAND	X-BAND
Wavelength	0.235 m	0.058 m	0.031 m
Swath Width	15 to 90 km	15 to 90 km	15 to 40 km
Pulse Length	33.8, 16.9, 8.5 us	33.8, 16.9, 8.5 us	40 us
Data Rate	90 Mbits/s	90 Mbits/s	45 Mbits/s
Data Format	8,4 bits/word	8,4 bits/word	8,4 bits/word
	(8,4) BFPQ	(8,4) BFPQ	(8,4) BFPQ

BFPQ = Block Floating Point Quantization, a form of data compression from 8 bits per sample to 4 bits per sample.

SYSTEM PARAMETERS:

Orbital Altitude	225 km
Resolution	typically 30 x 30 m on the surface
Look Angle Range	17 to 63 degrees from nadir
Bandwidth	10, 20 and 40 MHz
Pulse Repetition Rate	1395 to 1736 pulses per second
Total Science Data	50 hours/channel/mission
Total Instrument Mass	11,000 kg
DC Power Consumption	3000 to 9000 W

Imaging Radar Home Page

SINGLE SCAN

5/8-03

Draft

COMMENTS ON DATA BASES & SYNTHETIC VISION SYSTEM

by Dr. George C. Chang, Aviation Consultant
at the Second Synthetic Vision Workshop
at NASA Langley Research Center
January 27-29, 1998

(1) Due to significant differences between low-end General Aviation (GA) aircraft and air carrier large transports, in terms of aircraft construction and operations, more than one synthetic vision system will be required to serve various segments of the aircraft operator community. Some of the resulting systems may meet the needs of the low-end GA, while other more sophisticated ones may more appropriately address the needs of large transports carrying several hundred passengers over thousands of nautical miles. As an illustrative example, there must be freedom, for some aircraft operators, to choose between systems based on a less costly 2-D terrain database and those more expensive 3-D types. Similar choices should be available in terms of display methods, operational simplicity, etc.

(2) The resulting airborne synthetic vision systems need to deliver economic benefits in addition to safety benefits originally envisioned. To achieve market penetration/user acceptance, system capability for beneficial operational applications must be carefully defined. Examples of beneficial applications include: (a) Avoidance of Controlled Flight Into Terrain/Obstacles, (b) Selected aspects of Free Flight including Curvilinear Approach.

(3) The resulting systems need to fit into future aviation infrastructure with respect to, among others, (a) National Airspace System (NAS) architecture, and (b) air traffic management (ATM) operational concepts/flight procedures. International harmonization also becomes a must as system applications grow geographically.

(4) The resulting systems need to be affordable, capable of doing the job in a cost-effective manner, maintainable with ease, and user friendly with acceptable level of training requirements.

(5) To be effective, one needs to take an evolutionary approach to developing and implementing synthetic vision systems. The approach is to "build a little, and test a little, ..."

(6) Collaborative development work involving stakeholders in the aviation community can go a long ways to ensure program success. Early involvement is a must. History of avionics development is full of successes, "white elephants", and failures.

(7) Human Factors considerations are a must in synthetic vision system development.

(8) System engineering approach is essential to successful development of synthetic vision system, while taking full advantage of user experience and expectations.

(9) Meaningful system requirements can be gleaned from many documents, such as FAA Advisory Circulars, ORDERS, Operations Specs., ICAO/RTCA publications, among others.

(10) Airborne Databases may include those for:

- -- Terrain, Obstructions, and Noise Abatement
- -- IFR and VFR Moving Maps, Special Use Airspace, Instrument Approach and Airport Surface
- -- NOTAMS
- -- Aircraft Systems and Performance

(11) Good 2-D and 3-D terrain and obstacle database displays may enable predictive CFIT protection, while Moving Map displays may facilitate aircraft VFR and IFR operations, including instrument approach and airport surface movements.

(12) Synthetic vision overlay displays may increase airport capacity during low visibility operations.

(13) 2-D or 3-D topographical terrain elevation and obstacle data bases can be displayed to the pilot along with aircraft GNSS position. Aural warnings can also be used to alert the pilot. Some professionals have indicated: "Additional enhancements to this basic information display might include a concurrent display of escape guidance information superimposed over a combined terrain and moving map display. Unfortunately, before such systems can be relied upon for more than just a source of advisory information, there is a fundamental need for certifiable terrain data bases." To date, there are no published aviation standards or design guidelines with which to approve electronic data bases for air navigation.

(14) Some professionals have also indicated: "There appears to be a need for an extremely low-cost predictive CFIT protection capability for [in particular low-end] GA users. In this regard, a possible implementation might be nothing more than a display of the minimum sector or vectoring altitudes superimposed on top of (or below) a GNSS moving map display." It was also suggested that "For this GA application, consideration should be given to draping cultural data bases over terrain models to provide more information on such things as names of various forestry, lakes, vegetation, rivers, roads, railroads, state and county bordrs, and other 'synthetic VFR' information."

(15) On January 15, 1997, Vice President Al Gore, Chairman of the White House Commission on Aviation Safety and Security, announced the public release of National Imagery Mapping Agency (NIMA) terrain data. According to some professionals, "these data will provide 1,000-meter terrain postings for about 60 percent of the world's surface, along with higher accuracy terrain data within 50 nautical miles of 450 selected airports."

(16) Some aviation professionals have suggested: "An obstruction data base is needed to complement the above terrain data base. As envisioned, this new electronic data base would consist of airborne and ground site survey data of all man-made obstructions within, say, 100,000 feet of the departure end of runways. Data would be used to enhance aircraft safety

as well as to allow operators to add payload. For example, data could be used to reduce an aircraft's second segment one-engine inoperative climb gradient requirements. This would be especially helpful in mountainous areas and at airports located in an obstacle-rich environment. Information could be displayed in the cockpit (such as overlaid on a GNSS moving map or head-up display) to help flight crews adjust departure profiles, thus allowing them to avoid hazardous obstacles within the departure corridor. Revenue payload could be increased because the climb gradient could be sited for each specific airport/departure runway combination."

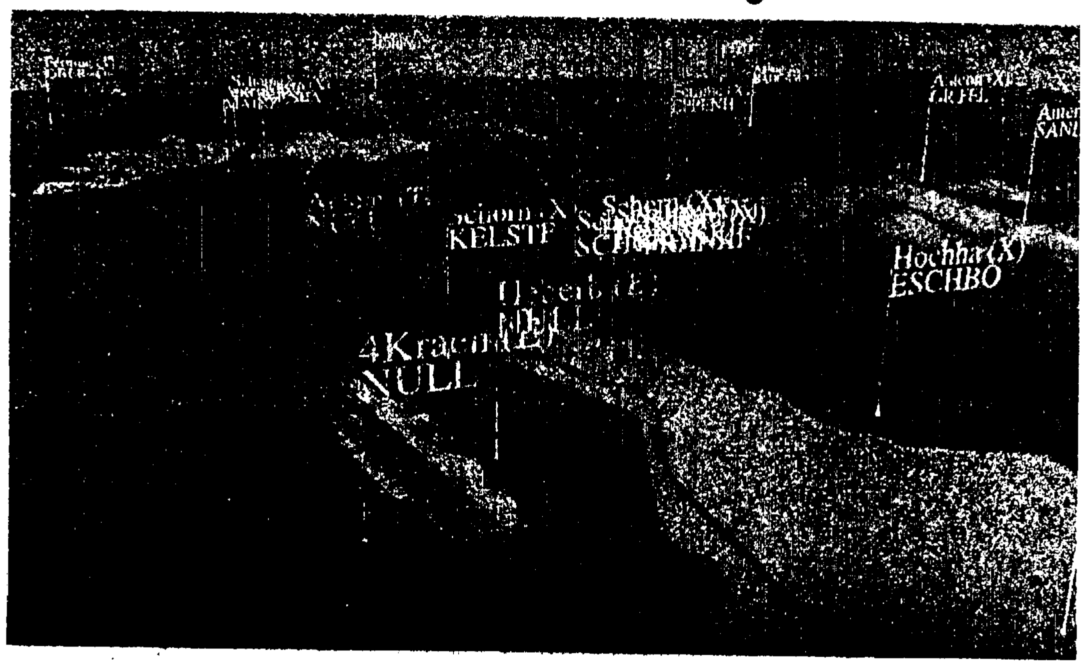
(17) To facilitate aircraft surface operations during low Runway Visual Range (RVR) conditions and at night, some professionals have pointed to the careful use of airport data bases: "Terrain, man-made obstructions, and other 3-D airport data such as information on the height of terminal buildings, hangers, and even aircraft, could be displayed to the pilot(s)... Own aircraft position data would be derived from GNSS data. ADS-B (Automatic Dependent Surveillance--Broadcast) data linked information would provide data on other aircraft. Use of this information would enhance night and low visibility operations, making the overall surface movement system more fault tolerant, and would provide redundancy and other benefits that would support the development of advanced surface movement guidance and control systems (A-SMGCS)."

(18) With regard to graphical depiction of noise sensitive areas for use in noise abatement arrival and departure procedures, some aviation professionals have suggested that: "Data on noise sensitive areas could be stored in an aircraft's resident electronic data base, then displayed as an overlay prooduct on an aircraft's GNSS moving map display. Using data link, air traffic controller could then electronically 'shift' these noise sensitive areas (and accompanying approach and departure corridors) during any 24-hour period to reduce the ground-based cumulative noise exposure levels." Obviously, some noise sensitive areas may feature certain terrain/obstacle data deserving appropriate attention within the context of CFIT avoidance.

(19) For the standardized curvilinear approach mentioned in Paragraph (2), some professionals have suggested that: "This proposed use of several electronic aviation data bases that synergistically work together comes directly out of the [RTCA] Free Flight Final Report. It makes use of data bases which contain terrain, obstruction, and published noise abatement data, then combines the data with prior aircraft- or ground-reported, data-linked winds aloft information... Benefits include reduced flying time to a point-in-space that is generically referred to as the GNSS Extended Final Approach Waypoint (EFAW)...Using this concept (in conjunction with a cockpit 'tunnel-in-the-sky' display presentation), only one approach waypoint along with one missed approach waypoint would be associated with any given runway, thereby reducing the need for multiple waypoints -- a safety factor that would result in less chance for charting errors. At low activity airports, aircraft would be allowed to automatically fly an approach to the EFAW. At busy airports, the [advanced] ground-based Center/TRACON Automation System (CTAS) would be used to assign '4-D' data linked waypoints to precisely guide the aircraft to arrive at the EFAW at an ATC-assigned time." Such a GNSS standardized approach would enhance not only operational safety, but also efficiency and capacity.

DB

Graphical Realtime Databases for Synthetic Vision Systems



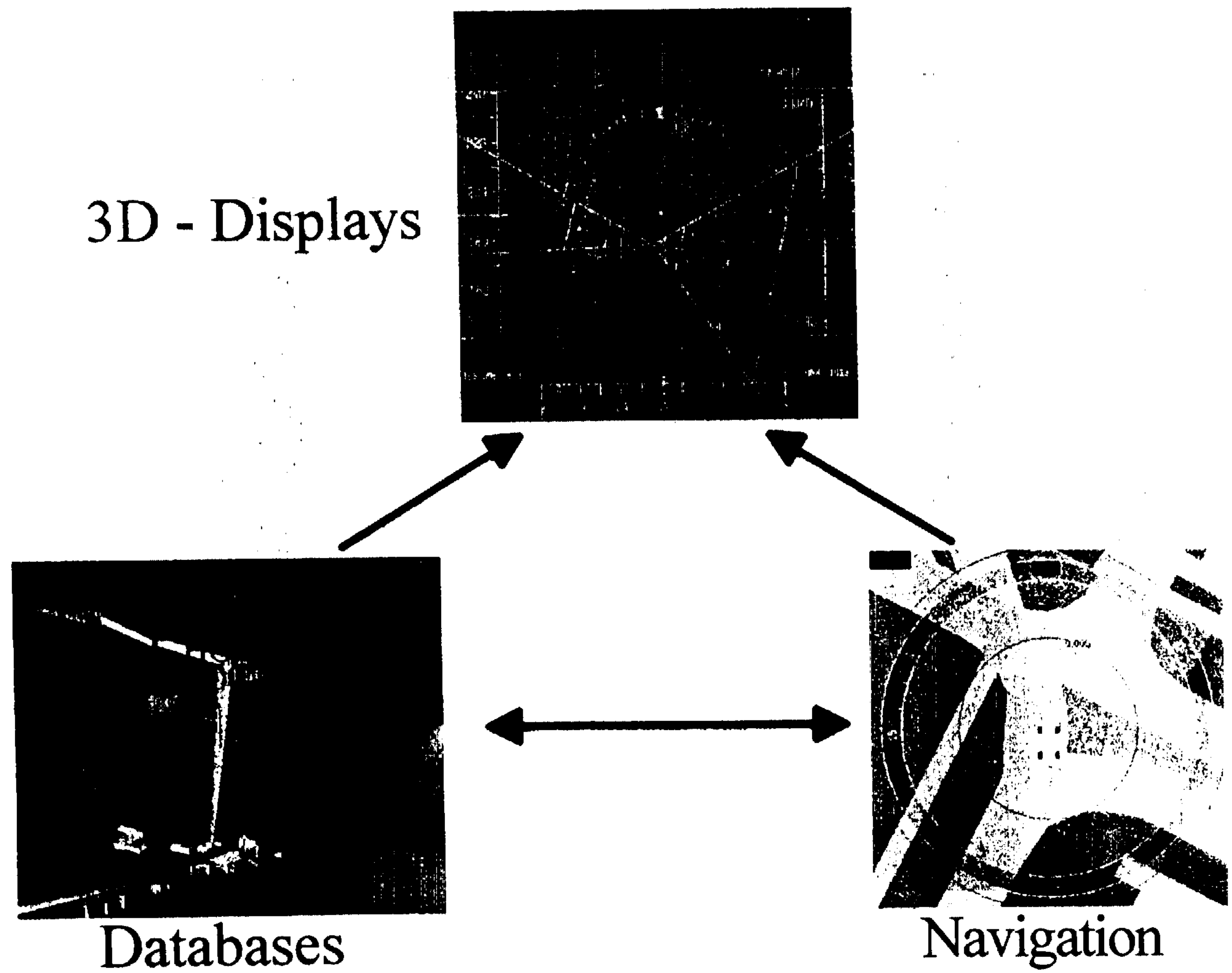
NASA Langley Research Center 1/98 Hampton, VA

by Jens Schiefele, Ludwig May, Helmut Raabe

Darmstadt University of Technology

S19-03

Introduction



DB: Data Sources

	Content	Class	Availability
Critical	NAV-Aids Airways ILS-Channels	NAV-Data	• wordwide avail. • in use
	Obstacles Runways/Thresholds Taxilines/Park.Pos.	Cultural Data	• ICAO Annex 11/15 • for 12/1997 required • error smaller 1m

Advisory	Terrain	Terrain Data	• worldwide available • different sources • verification started
	Rivers/Roads/ City Outlines Airport Buildings	Cultural Data	• partly available

DB:Nav-Data Creation

- **Contains Errors**
  - Data is from National AIPs
  - Different Reference Systems (WGS84, Bessel, Krassowski, etc.)
  - Country dependent Accuracies and Updates
- **Data Must be Verified**
  - Demand will force National Authorities

DB: Terrain Creation

Different Satellites

- SPOT, Landsat
- IRS-1, ERS I-II, Ikonos 1, etc.

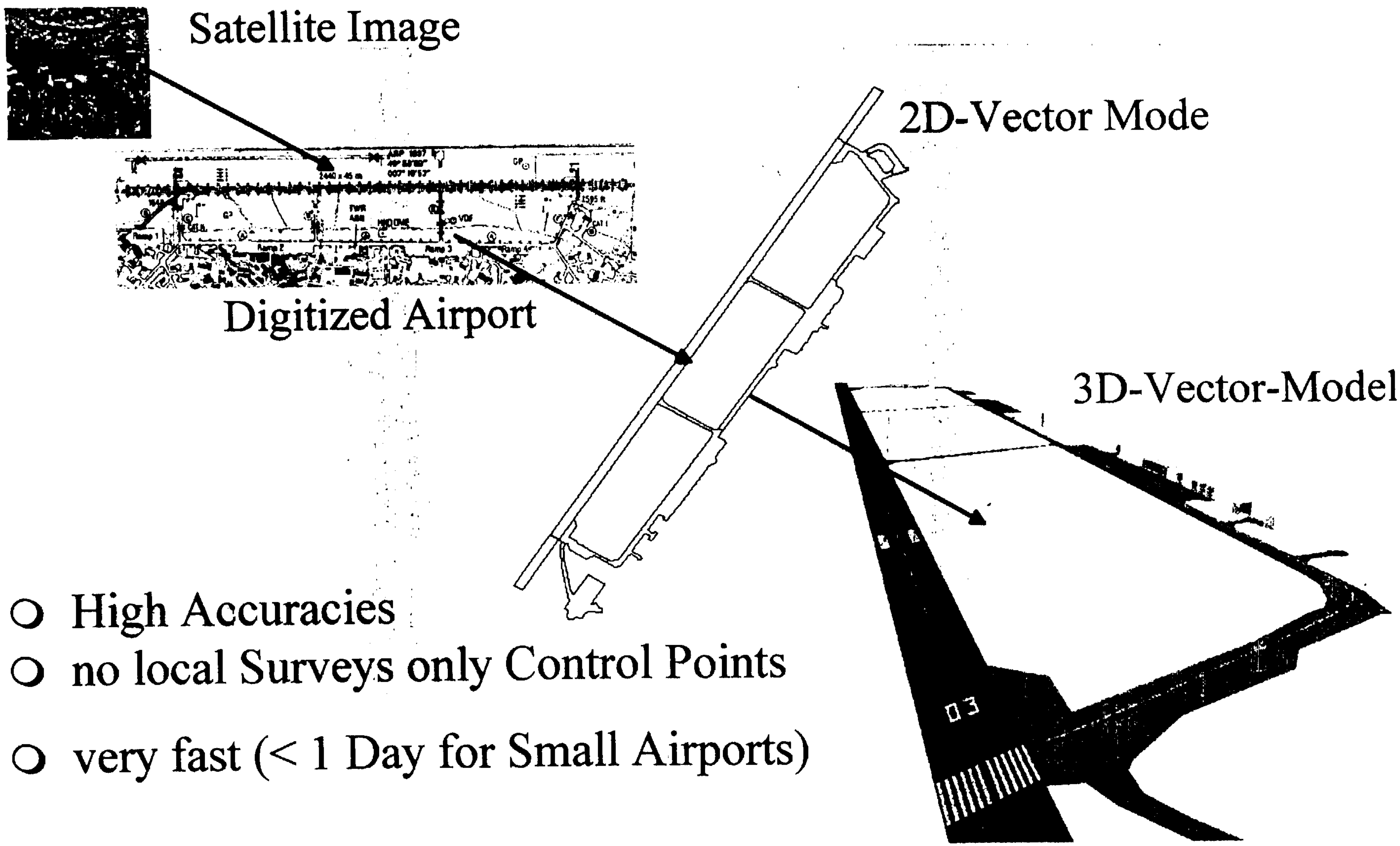
Generate independent DEMs

- different Acquisition Methods and Sensors
- different Terrain Generation Methods
- World Wide Coverage

Verification of DEMs by Terrain Correlation

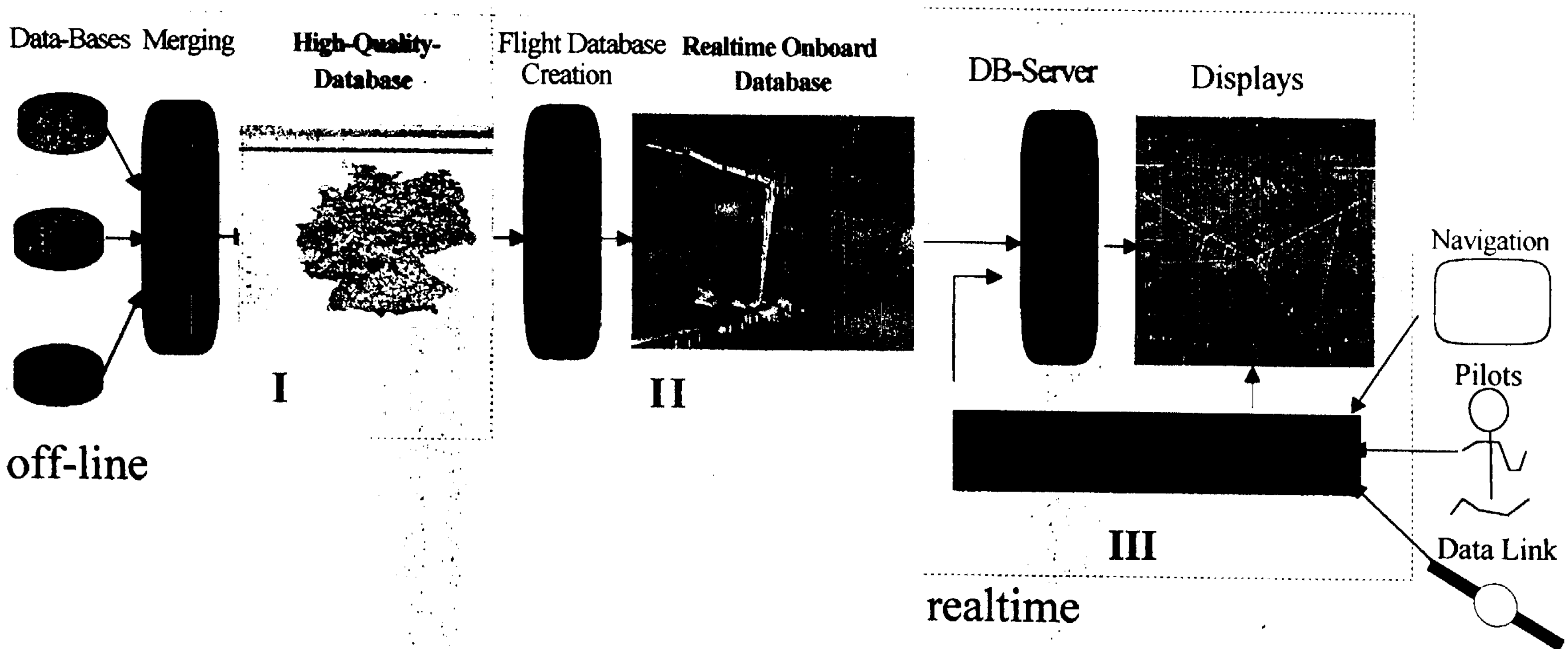
- Weighted Elev. Post Average
- Standard Deviation for Uncertainty

DB:Airport Database Creation



- High Accuracies
- no local Surveys only Control Points
- very fast (< 1 Day for Small Airports)

DB: Database Concept

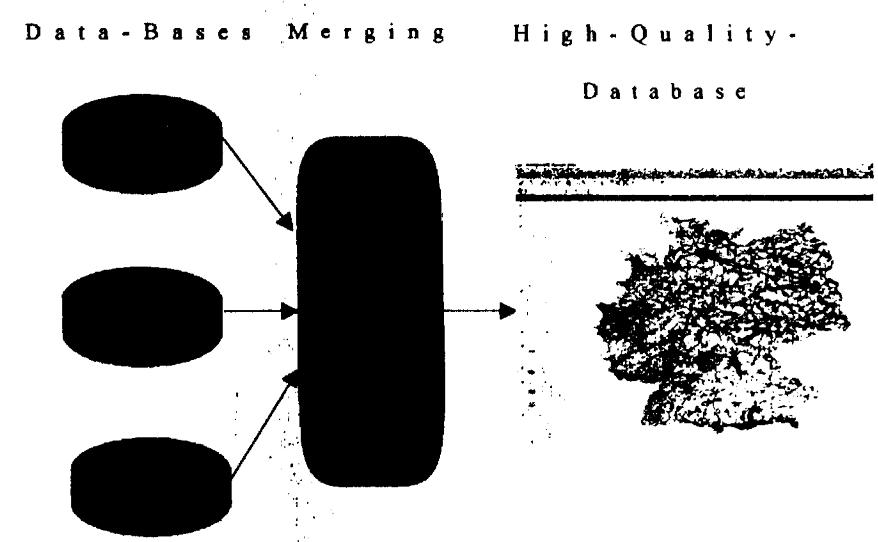


I. High Quality Database Creation
II. Realtime Onboard Database Creation
III. Database Server

DB: High Quality Database

Geographical Information System (GIS)

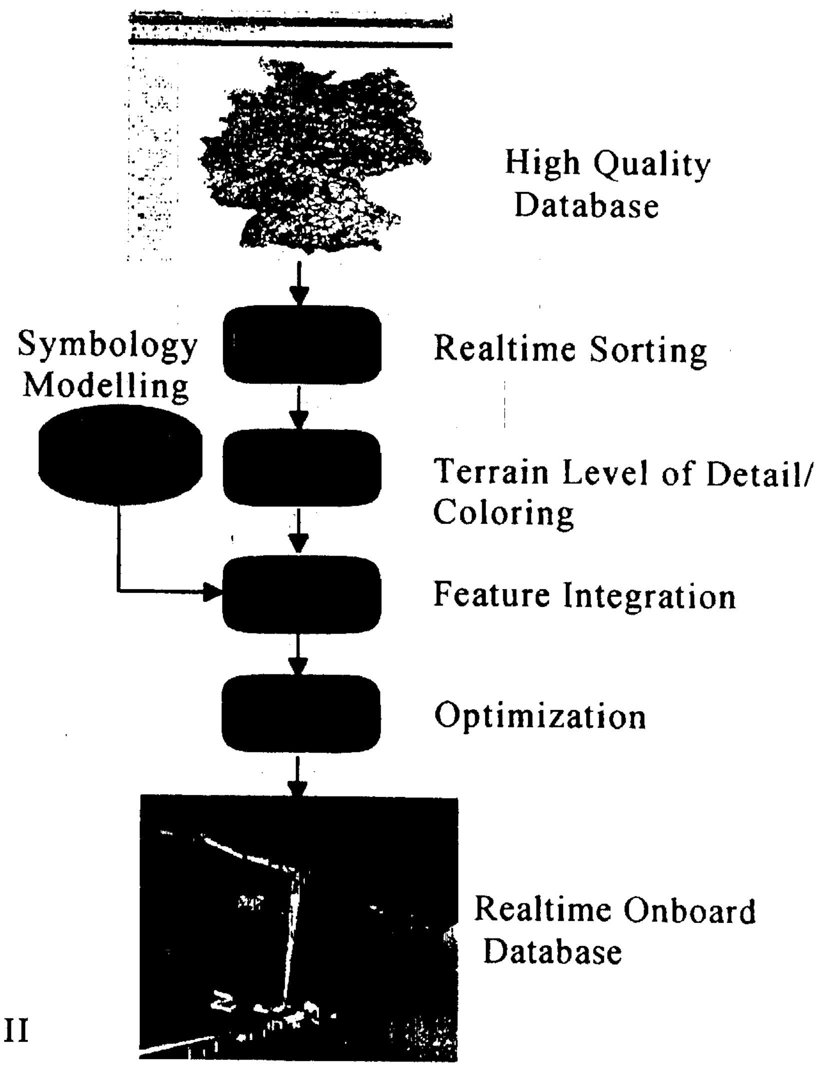
- Huge Databases
- Consistency
- Coordinate Systems
- all needed Data Types



DB: Realtime Onboard Database

Realtime Conversion

- Realtime Format
- Object Identification
- Data Reduction
  (LOD, Optimization)
- Integrated Symbology

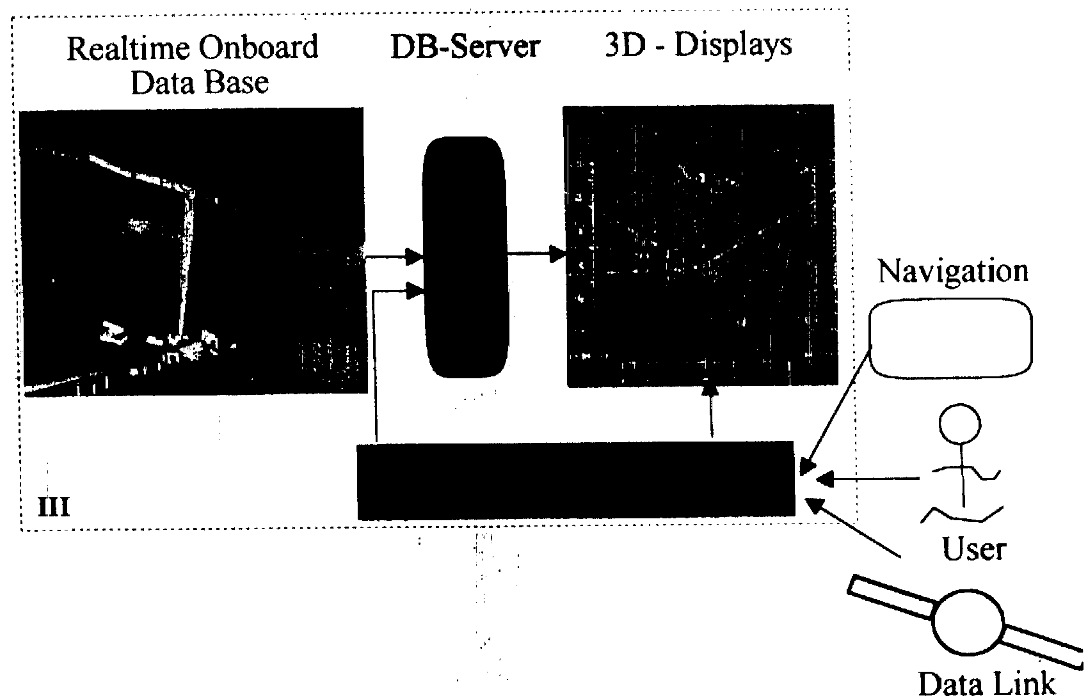


II

DB: Database Server

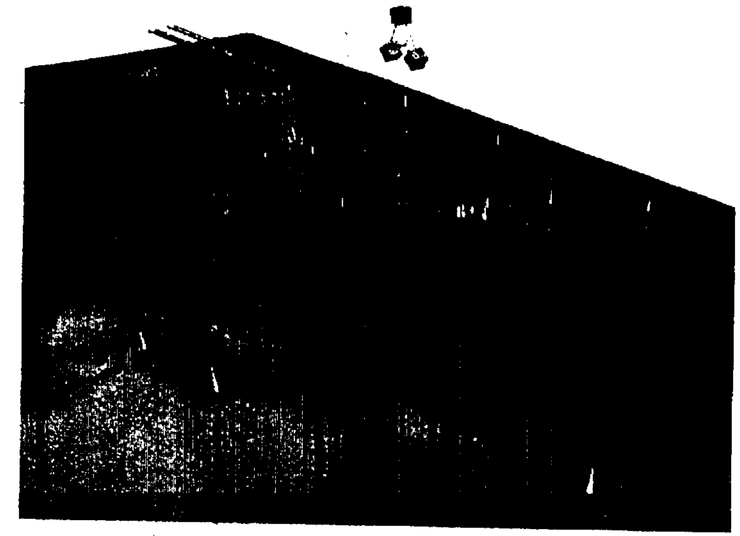
Database Server

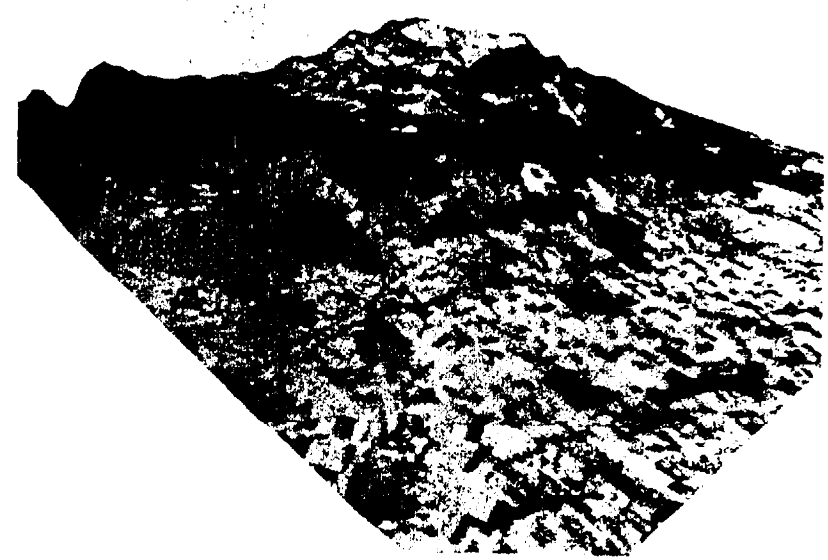
- Nav Update
- NOTAM Update
  (Data Link)
- Weather Update
- User Update
- Tile Selection



DB: Applications

- **Prototyping Database:**
  - 3D PFD and 2D ND
  - Simulator Visual
- **Rapid Prototyping:**
  - Frankfurt (< 1 week)
  - Hahn (< 1 day)
  - Braunschweig (< 2 days)
- **Flight Tests (in Germany)**





DB: Issues I

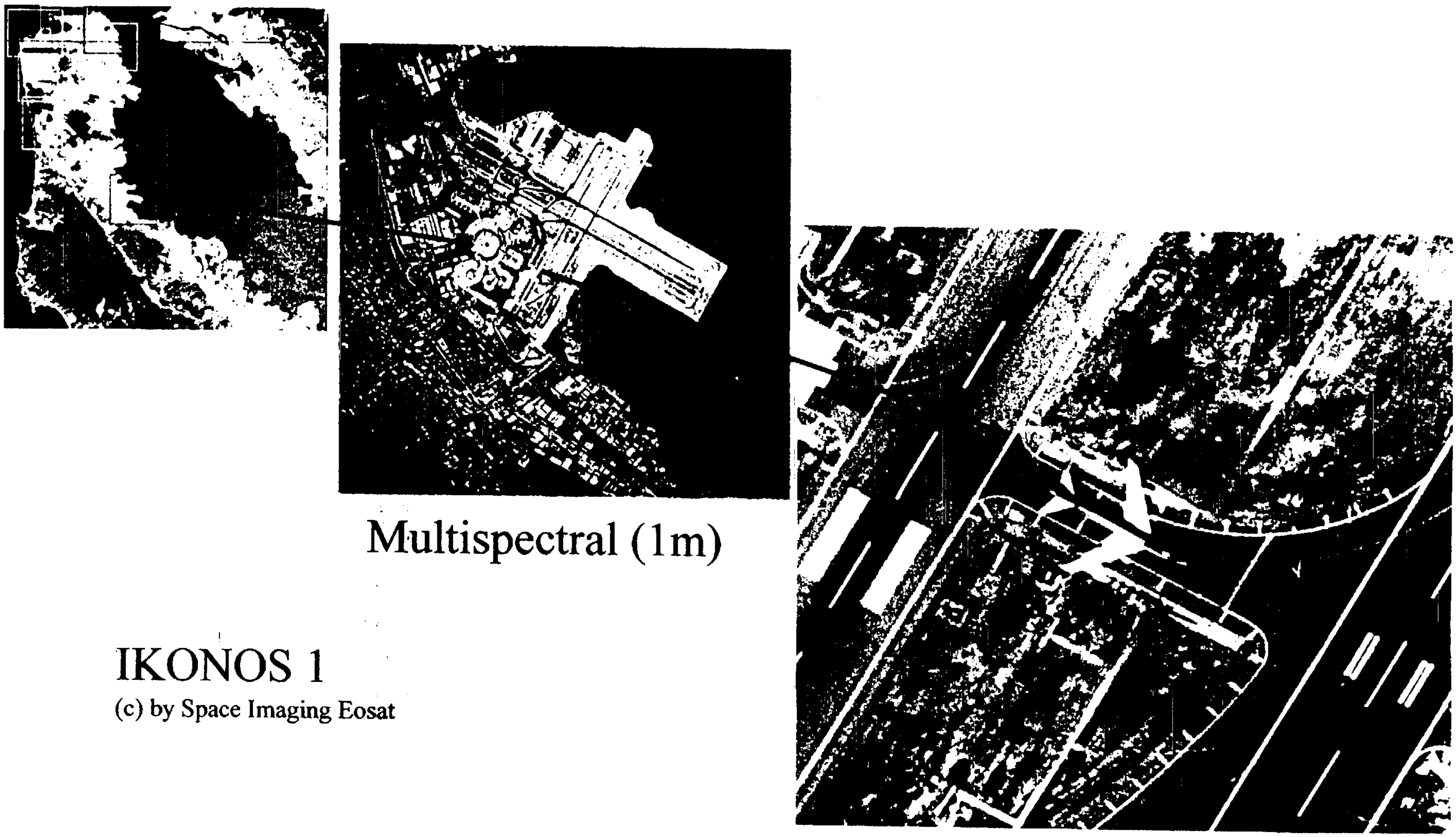
- **Define/Standardize Certifiable Processes**
  - Data Acquisition
  - Data Handling
  - Data Conversion
  - Data Distribution
- **for following Datatypes and Criticallity Levels**
  - NAV-Data ➲ critical
  - Terrain ➲ advisory
  - Airport (Cultural Data) ➲ critical

DB: Issues II

- **Standardize File Formats for**
  - High Quality Database
  - Realtime Onboard Database

- **Develop Concept for Short Term Data Integration (DataLink)**
  - Controller Commands
  - NOTAMs
  - Weather

Satellite Images - IKONOS



Multispectral (1m)

IKONOS 1

(c) by Space Imaging Eosat

S20-06

Combining Synthetic Terrain and Pathway-in-the-sky for Head-up Display

Michael P. Snow

January 28, 1998

Combining Synthetic Terrain and Pathway-in-the-sky for Head-up Display

- Flight Display Integration Program
  - Five-year exploratory research program
  - Goals
    - Meet two Air Force Needs
      - Operations in low/no visibility
      - Reduce CFIT
    - Produce next-generation primary flight display

Combining Synthetic Terrain and Pathway-in-the-sky for Head-up Display

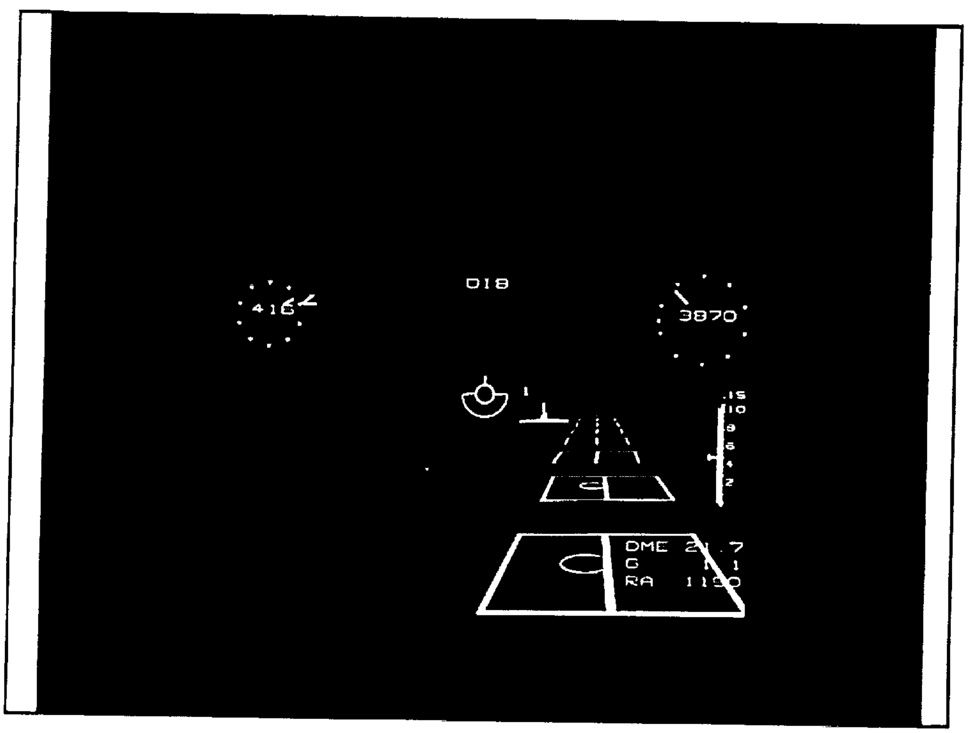
- Flight Display Integration Program
  - Approach
    - Allow pilot's attention to be focused outside the cockpit
    - Display 3D information for a 3D task
    - Focus on CFIT cause: poor or lost SA

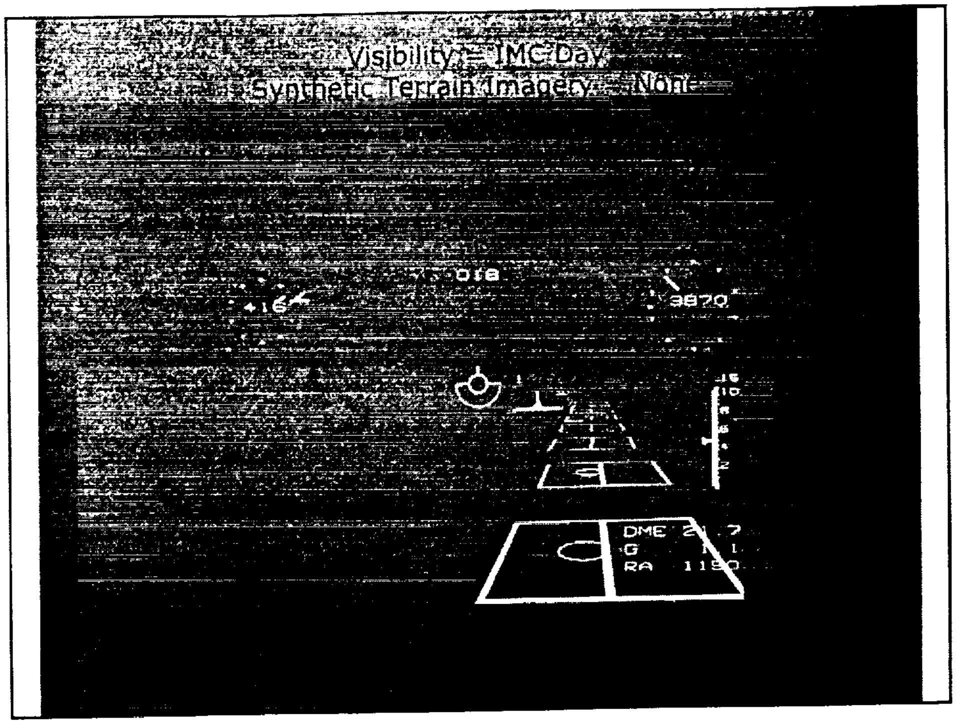
Combining Synthetic Terrain and Pathway-in-the-sky for Head-up Display

- Previous research
  - MILSTD HUD vs. Pathway
    - Flight performance better for pathway
    - Pathway preferred
  - VMC vs. IMC
    - Flight performance with pathway equivalent regardless of visibility

Combining Synthetic Terrain and Pathway-in-the-sky for Head-up Display

- Current research
  - Pathway and Synthetic Terrain
  - Optimization of Pathway Symbology

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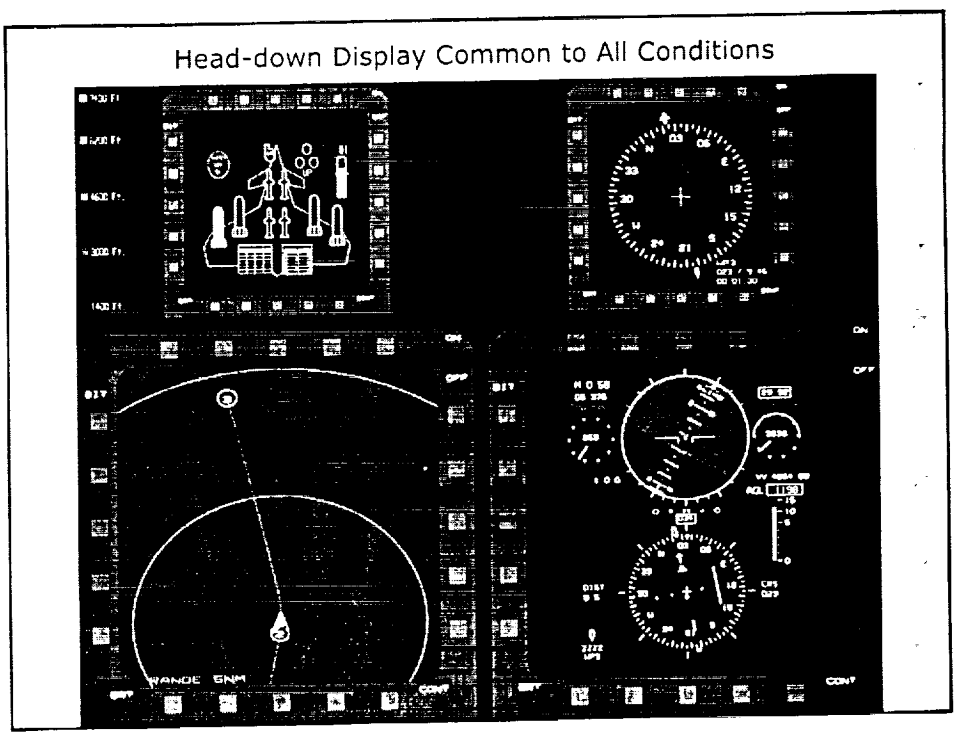
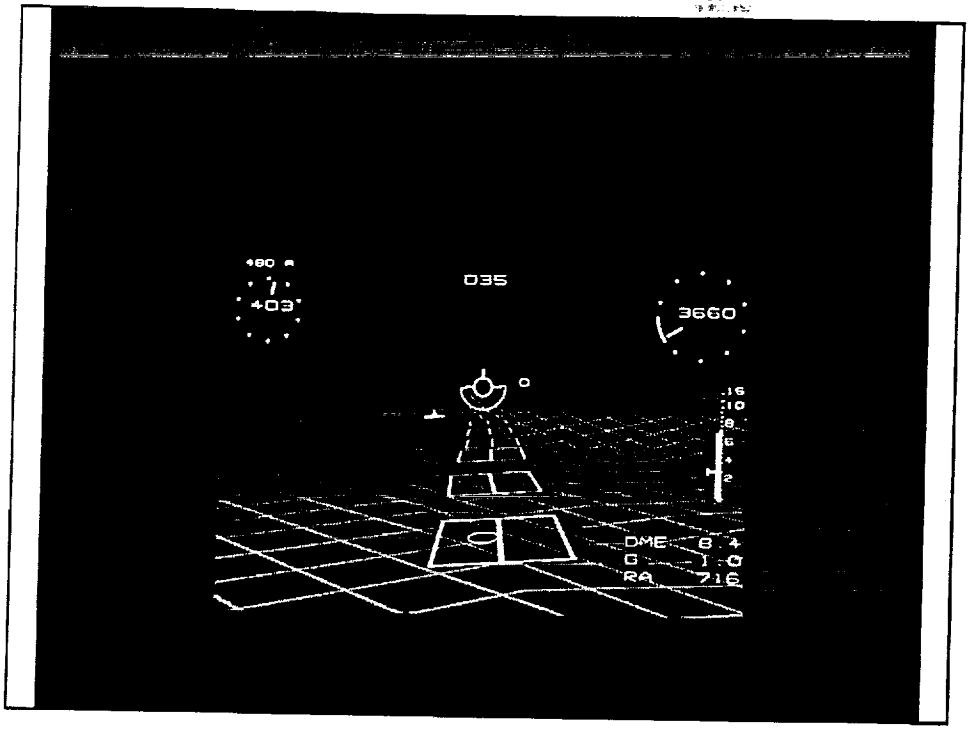
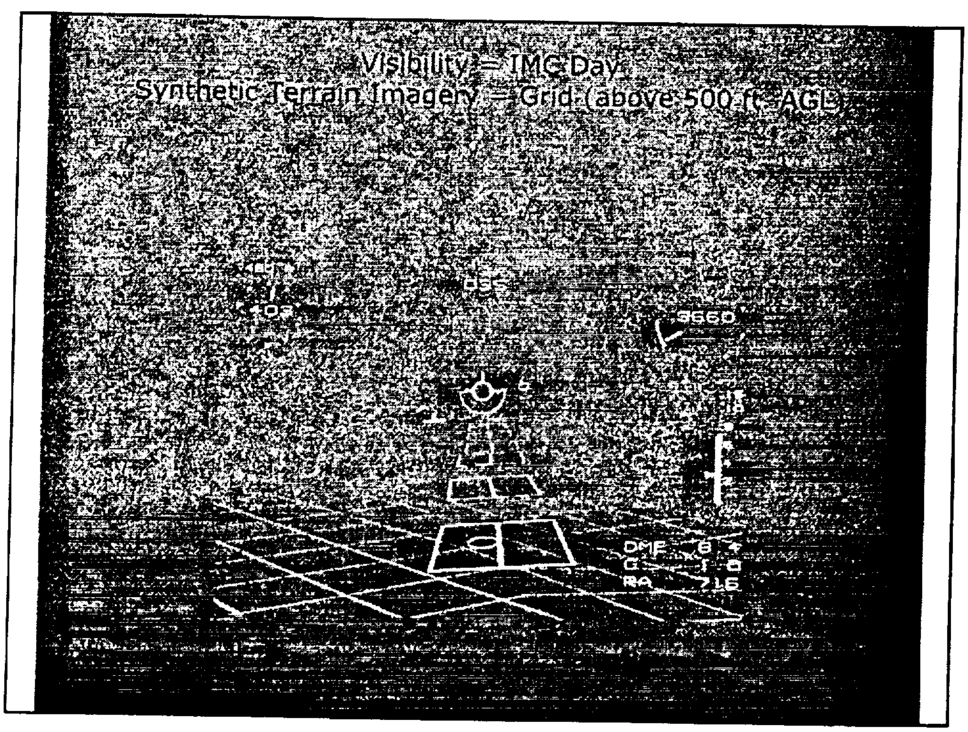
Synthetic Terrain Imagery = None
DME
RA


Head-down Display Common to All Conditions


403
035
3660
DME 8.4
G 1.0
RA 716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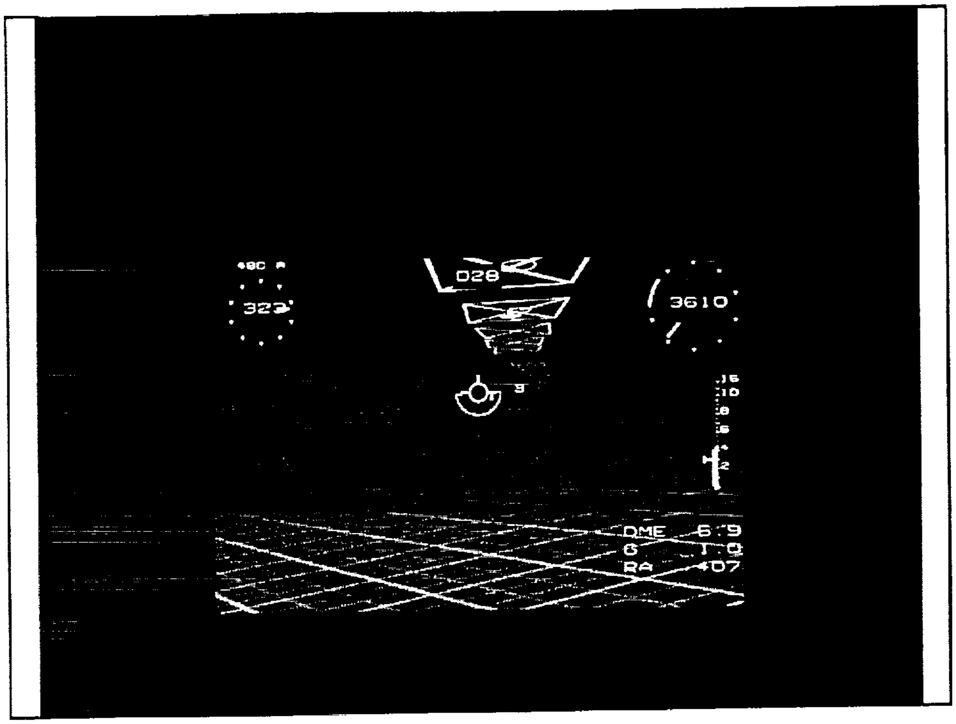
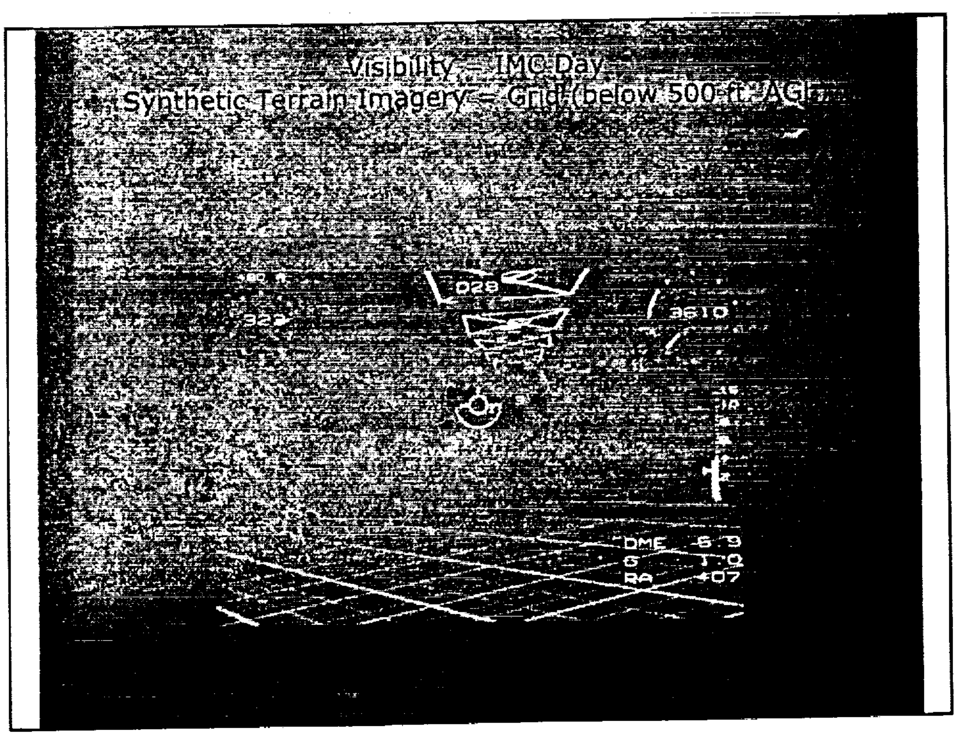
Synthetic Terrain Imagery = Grid (above 500 ft AGL)
3660
DME 8.4
G 1.0
RA 716



DME 6.9
G 1.0
RA 407



Visibility – IMC Day
Synthetic Terrain Imagery – Grid (below 500 ft AGL)
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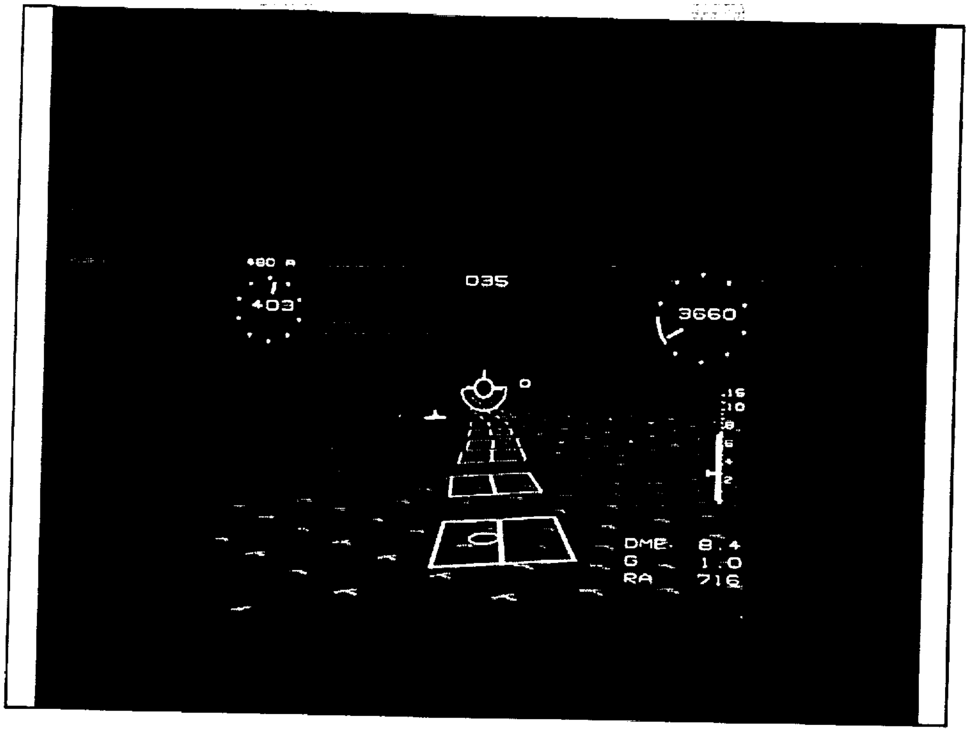
G 1.0
RA 407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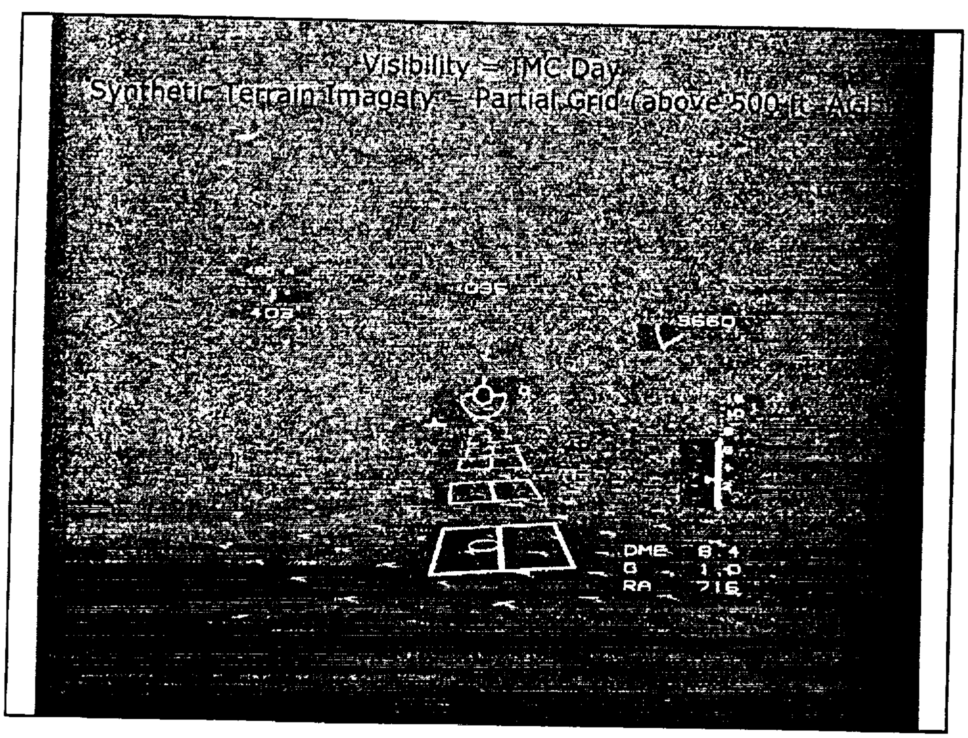
DME 8.4
G 1.0
RA 716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Synthetic Terrain Imagery = Partial Grid (above 500 ft AGL
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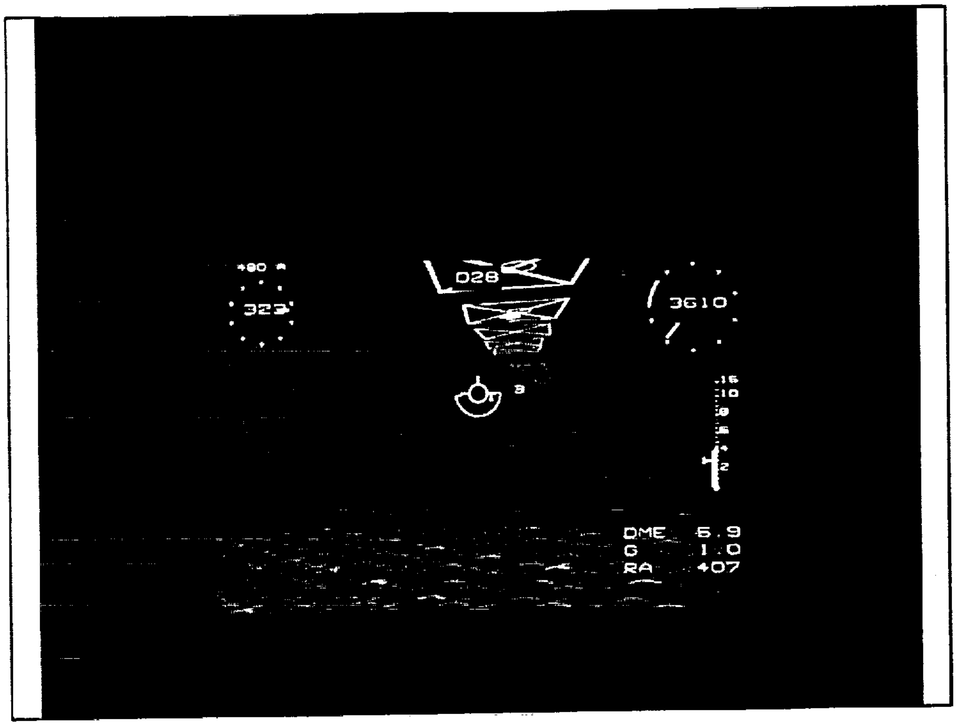
G 1.0
RA 716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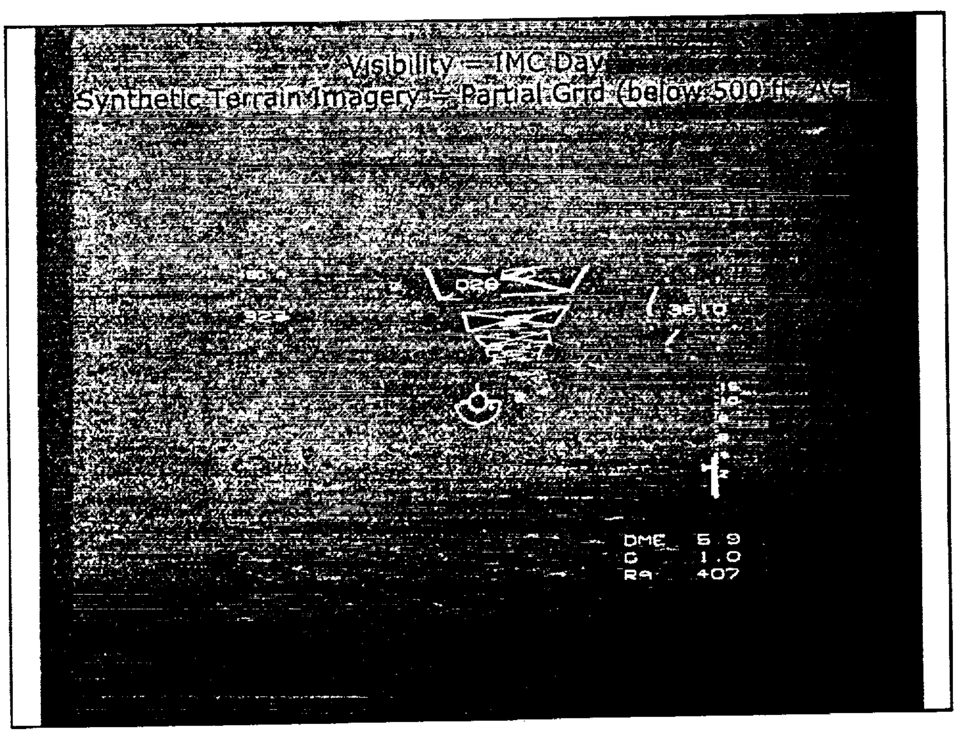
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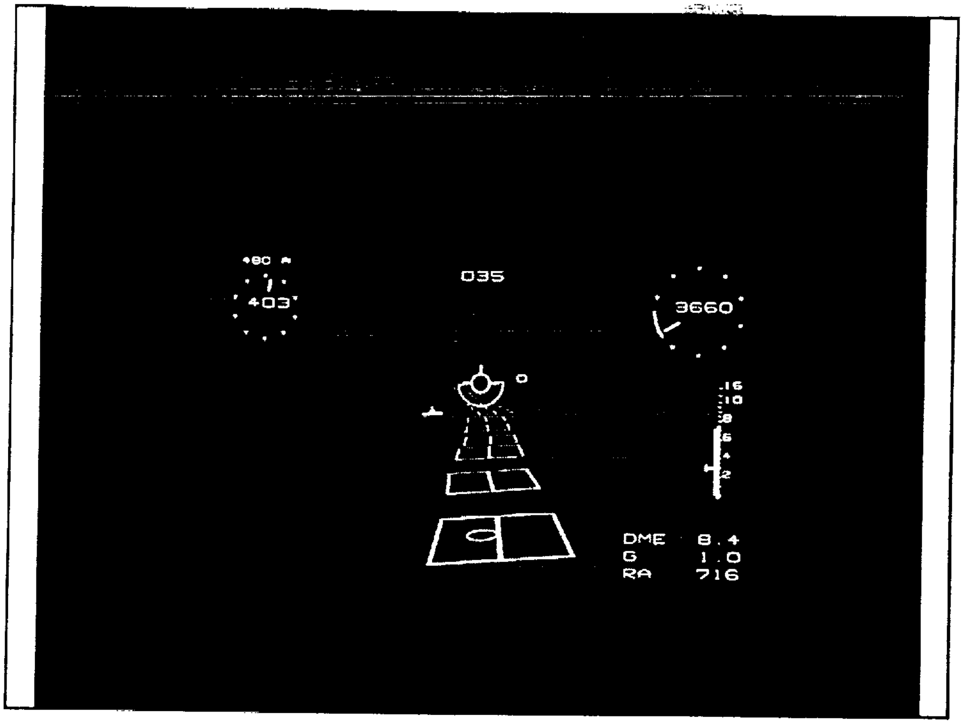
028
DME 5.9
G 1.0
RA 407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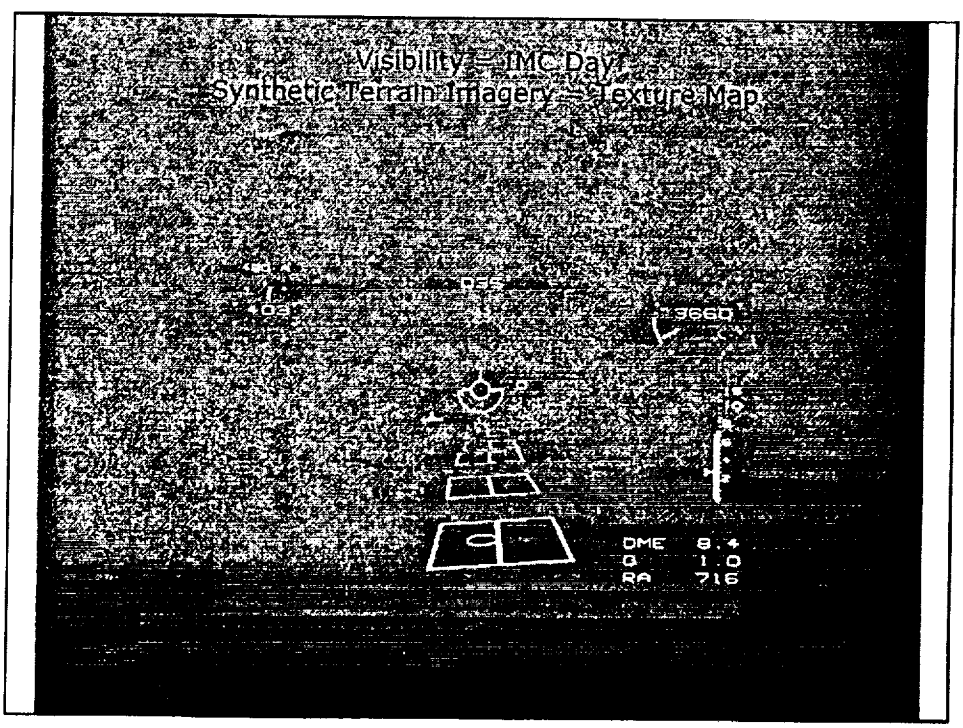
Visibility = IMC Day
Synthetic Terrain Imagery = Texture Map
403
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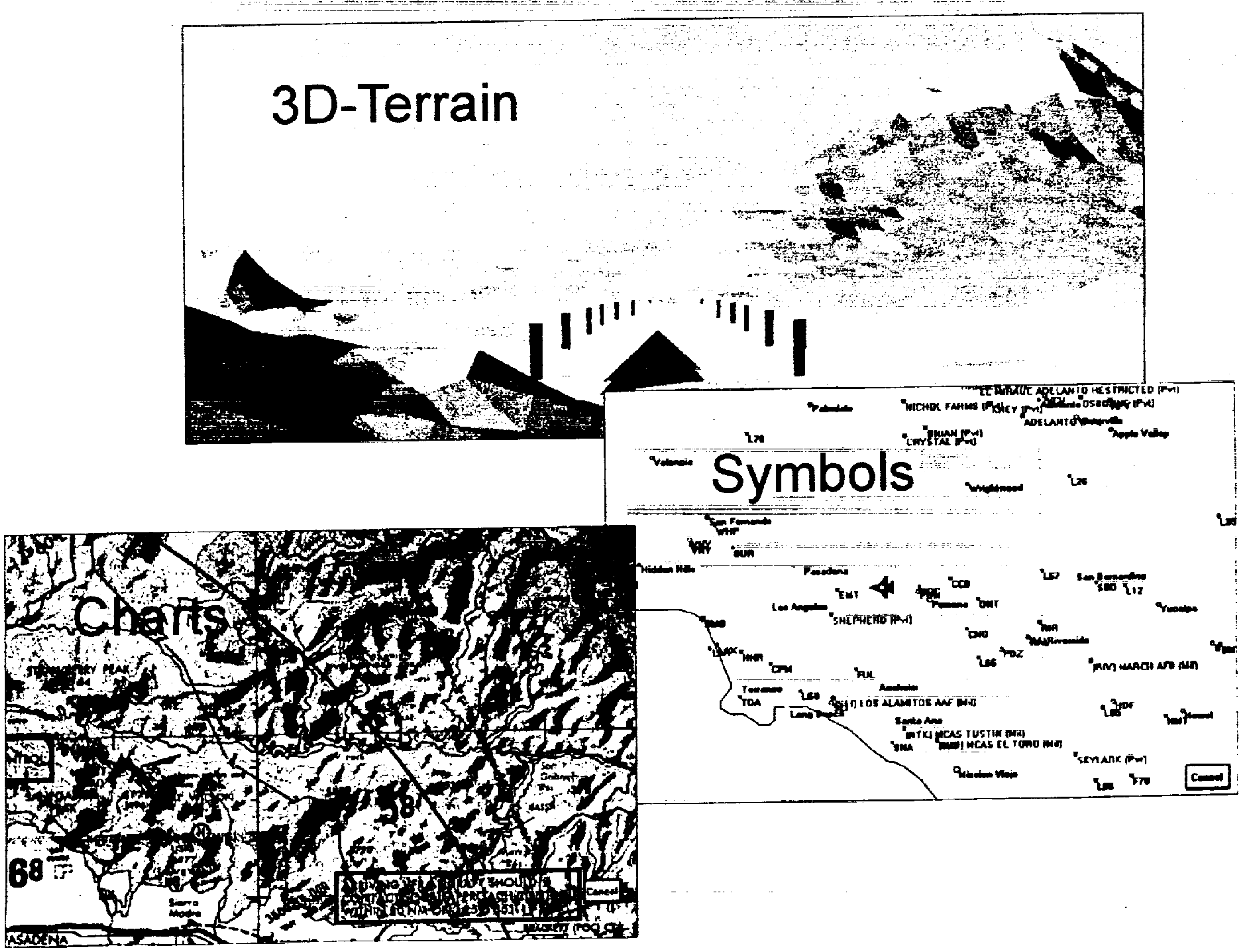
DME 8.4
G 1.0
RA 716

free flight™

SINGLE-SCAN

531-04

Lynda Foernsler
NASA Langley



www.free-flt.com

Free Flight Inc., 975 North Michillinda Avenue, Pasadena, CA 91107 (626) 791-0400

Free Flight and Synthetic Vision

for the January 1998 Synthetic Vision Workshop, NASA LARC

The Origins of Free Flight (the computer program)

The original 1980's moving maps were simple. They had an airplane icon moving on a small display relative to a course line. Airports and VORs showed up as symbols. This was a great step forward over tracking a Course Deviation Indicator and a step up over an HSI, a sort of mechanical moving map. As a pilot, flight instructor (having taught private, commercial, instrument and aerobatic students) and someone in the computer industry, I followed this technology closely. Most of us knew this human interface could be improved.

From the late1980's until the early 90's I kept expecting someone to develop a moving map with digitized aeronautical charts and a 3-D Terrain/Synthetic Vision display. And I waited, looking for this display. In late in 1992, with no such product in sight, I abandoned the wait and began development. The technology existed to do the job at a reasonable cost.

The result was Free Flight, commercially released as a moving map program in May of 1996. It had a symbolic presentation, digitized charts and a 3-D Terrain display based on early Dept. of Defense DEMs (Digital Elevation Models). It was named in honor of the Free Flight concept, which the FAA is moving toward with Flight 2000. The name is also an expression of the goal of the product; a synthetic environment allowing a pilot to fly more safely from one point to another in IMC, as if flying in VFR conditions, and flying free of ATC control for most of the flight. We've had a first generation synthetic vision display for over a year.

As a pilot, it never occurred to me to question whether or not we should have a synthetic vision display. It was obviously the way we should be flying. Synthetic vision may not be necessary at all times but when it is needed, it's needed desperately and can save lives. I suspect that once it is properly implemented, it will become an indispensable tool to all pilots, worldwide.

Each of Free Flight's three modes, Symbols, Charts and 3-D Terrain, uses a separate source of data for it's presentation. This provides a data cross check, one against the other. The Symbols mode is a vector display using a database. The Charts mode consists of digitized and geo-referenced aeronautical charts. The 3-D Terrain mode is built from elevation data in a DEM file.

GPWS and enhancement to 3-D Terrain

In December of 1996 I was working on improving visual cues for the pilot to prevent CFIT. The result was a GPWS having paired "objects", or vertical bars, spaced at one-mile intervals, adjacent to the projected flight path of the aircraft, presented in a realistic representation of terrain. The design created a visual perspective to the aircraft's GPS altitude as well as a GPWS. As the aircraft approaches terrain, the vertical GPWS bars 7 miles out disappear into the terrain. Then those at 6 miles disappear and so on, counting down the distance to terrain impact. It's quite effective and the impending collision becomes more obvious as the terrain is approached. This technique proved to be workable in flight tests and was shipping in the commercial product three weeks later.

We also added cones on the ground to mark airport locations so pilots could find the airports more easily. User waypoints were marked as yellow cylinders sticking up vertically out of the ground in the 3D space. When the user creates a waypoint, it is saved with the altitude of that lat/long from the DEM file. Many Free Flight users have found great applications for this simple feature.

The 16 bit limit

Free Flight has been a 16-bit program originally developed in the Microsoft Windows 3.1 environment on Intel 486 CPUs. We had to limit the terrain display update rate to give the computer enough time to create a new terrain display. If this had not been done, the computers we were using wouldn't have been able to keep up with the GPS input they were receiving. We set the terrain display update to occur every 15 arc seconds of flight, or about every quarter mile. This worked out well because we use a 15-second DEM data in creating the display. A Pentium 233 MHz CPU can update a terrain display with a 13-mile view in slightly more than a second. This is fine for most applications. For example, a B1B pilot called me the other day and mentioned flying missions at 9 miles per minute at low levels. This version of Free Flight could keep up with him on a Pentium 233 system. He'd be looking ahead one minute and twenty-six seconds. Free Flight certainly would not be recommended as his primary means of terrain clearance, but it would give him an idea of the terrain ahead and is of value in preventing CFIT.

A 166 MHz Pentium takes almost two seconds per frame with a 13 mile forward looking range and would be slightly underpowered for the B1B missions. The pilot could reduce the complexity of the terrain rendering or cut the viewing range down to 6 or 7 miles. Either or both actions would increase the display speed. Free Flight is pilot adjustable to optimize settings for speed or aesthetics.

The 32 bit opportunity – our state of the art

We began moving Free Flight over to the 32-bit environment in the summer of 1997. This gave us access to the power of 32 bit CPUs and vastly superior software development tools and programming methods. Our latest synthetic vision display runs between 3 and 21 frames per second on a Pentium 200. We have the speed to keep up with a space vehicle flying a reentry. The terrain module is near completion and we have begun integrating it into the main part of the Free Flight program.

The GPWS has been changed and may not be in its' final form yet. Our methods of terrain rendering have improved and there's more that we can do. We have vastly increased the number of objects we present in the terrain display to include runways, obstructions, navaids, etc., all of which are subject to change. We are "flying" in the synthetic vision space with a joystick.

A few lessons learned

The following points seem obvious based on my experience in developing Free Flight over the past years but perhaps I have been biased from the start:

- A synthetic vision display should be the primary flight display. It does one thing *exceptionally* well; it reduces the possibility for pilot disorientation and confusion that can lead to further mistakes and build into an accident chain of events. The pilots "out the window" view with synthetic vision provides a natural and instant terrain awareness and orientation. Synthetic vision displays bypass the mental processes involved in interpreting and correlating many separate instrument alpha-numerics, a task which increases in difficulty during stressful times.
- Synthetic vision can replace many panel instruments if properly done.
- A synthetic vision display can not be placed (retrofitted) in the same space as an ADI/attitude indicator currently used in transport aircraft. That space is too small. The synthetic vision display needs to be large, 14", 21" or greater. A HMD can create a virtual display 10 to 15 feet wide!
- A good synthetic vision display can provide useful terrain awareness and is valuable in preventing CFIT, perhaps to the point of eliminating it. This point alone should reduce airline insurance policy expense enough to justify them funding synthetic vision development, certification and installation/retrofitting.
- A good synthetic vision display can provide a better understanding of the terrain than looking at a chart, relief map and sometimes better than looking out the window in VFR conditions.
- In mountainous areas a 15 arc second DEM terrain rendering provides better terrain awareness than looking at a Sectional Chart.

- Thirty arc second DEMs make the terrain look unnaturally flat, but are useful for terrain avoidance.
- A good synthetic vision display has many other uses than simply preventing CFIT. It can provide information for navigation, provide information on weather, traffic conflicts, airport location, help firefighters, crime fighters, help students in classrooms and will have other uses we haven't thought of.
- Visual cues such as texture mapping are vital to show pilots how close to terrain they really are.
- It is very easy to "kludge up" a synthetic vision display to the point of providing too much distracting clutter, reducing it's usefulness. It must be kept as simple as possible.
- We can get a 30-second DEM of this planet on one CD-ROM, with room to spare.

Areas of research and development Free Flight should undertake:

I. The HMD (Head Mounted Display).

Free Flight was built for portability and for use in a wide variety of flying missions. We can rapidly develop a notebook driven HMD system, creating a complete package for synthetic vision applications in navigation, research and development, testing and other areas. Free Flight is well positioned to do this.

The concept is to create a wireless HMD that can interface with a carry-on notebook computer or can work with a flight deck system. While this is under development, create the high-end thrust for transports and low end hardware for general aviation. The notebook computer should have a small black box, which rides along with it. The "ride along" system would contain a pressure altimeter that can plug into the static system for accurate altitude readings, ring laser gyros to provide pitch, roll and smooth intermediate positions between GPS updates and a 12 channel GPS receiver. The HMD synthetic vision display should have an aircraft vector so the pilot can see where the airplane is headed. The system becomes a carry-on avionics/navigation package with battery backup for an hour or more of flight if all on-board electronic systems fail. Parts of this package could also serve as a highly portable training system for pilots.

HMDs are theoretically the best method of user interface at this time. HMDs provide a pilot with "the big picture" in a way that no other display can. With head position sensors (sonic or infrared, *not* accelerometers) a pilot can turn his head and see *through the airplane* by looking in any direction. That's a great freedom and how he gets the big picture.

The technology for HMDs is just maturing to the point where they are economical and practical. HMDs offer the ultimate convenience because of their high degree of portability. They can be used with a notebook computer and easily carried on and off of the airplane. The notebook can be stowed with the HMD attached to it by a cable providing great cockpit freedom. An HMD could be plugged into a jack on the instrument panel to connect with a built in on-board computer or use a wireless input/output system with no cables at all.

The HMD will have a microphone for voice control of Free Flight, without the need to use a mouse, keypad, joystick, or trackball. Voice command is the ideal user input at this time. Small LCD's suitable for HMDs are now available in 640 x 480 resolution. In the near future, Micro Vision Imaging of Seattle with offer Laser Retinal Imaging which has near photographic realism and variable visual immersion. By using a visual input for each eye, a true 3-dimension effect can be created with simple computer logic. The new Universal Serial Bus and Firewire I/O ports on computers are very fast and will benefit head position sensor response time.

II. The high end thrust.

Free Flight can provide a short path to synthetic vision in transport aircraft because it is a second-generation product. By accessing the data on the Flight Management Computer and feeding it into Free Flight, many certification problems will be bypassed. We will not be changing FMC data; simply rearranging it's presentation. The only new thing Free Flight would bring to the table is a working synthetic vision display. Everything else will simply be a different way of displaying data from the FMC. The steps to take are: a) Build an interface to the FMC via a ARINC 429 card installed in a Pentium based system so we can read the desired FMC data into Free Flight. b) Construct a highway in the sky using FMC inputs and construct other, simple pilot interfaces, such as a pitch ladder, heading display and a few other things, all with FMC data. c) Test the display in a flight simulator with pilots and modify it as needed. d) Test the system in-flight while working with the FAA towards certification. e) Add TCAS data so pilots can see and avoid potential collisions f) Add hazardous weather, including wind sheer, to the synthetic vision display. g) Add airport detail visuals for taxiing to the gate. h) Make final adjustments, obtain certification for the software and hardware as well as any retrofitting/installation of cockpit hardware. i) Deploy a workable system so that a pilot can fly in IMC and have the perception he is flying VFR. j) Add other items as needed in the future.

III. The low end thrust.

The resources of an FMC are not available in a light airplane or helicopter so we'd need to expand our database slightly and put together reliable hardware, probably driven by Windows NT 5. A program would be to: a) Fill out the Free Flight database with sufficient data to build a highway in the sky. b) Develop a dynamic highway based on the pilots flight plan. c) Integrate the B.F. Goodrich for TCAS information and the Strikefinder. d) Integrate a datalink to upload weather information, perhaps from a commercial service ... while working with the FAA toward certification of hardware and software. e) Develop or integrate ring laser gyros to provide pitch and roll information. f) Complete certification of the software in a hardware package. g) Deploy the package.

IV. Free Flight program enhancements.

Future Free Flight enhancements to be implemented are: a) Texture mapping of the earth model with aeronautical charts. b) Voice control of the program. c) Complete the database with all available NOAA data in it and a program for auto updating the data. d) Build the highway. e) Interfacing with the Goodrich TCAS, the Stikefinder for Wx. or Michigan State University Jeff Burl's GPS squirter through s-mode transponders and present them in the 3d space. Bad Wx can be laid over aeronautical charts. f) Create multiple resolution DEMs: 6", 15", 30", 1' and 5' and integrate their use into Free Flight. g) Clean up of existing DEM accuracy to have them more closely match the real world. One method is to create a program to adjust the DEM elevation where there are points of know elevation, such as airports, navaids or the bases of obstructions. This is the quest for the Golden (perfect) DEM. h) Build special-use-airspace in the synthetic vision space. i) Develop a HMD as noted above. j) Develop a solid state ring laser gyro system for pitch and roll input to Free Flight. k) Do the same with a pressure altimeter for accurate altitude input (we currently depend on GPS altitude). l) Develop a touch screen interface until a HMD is ready. m) Calculate and display an aircraft vector so a pilot can see exactly where the airplane is going.

V. Generate instrument approaches on the fly.

This would partially be an implementation of the work Andy Barrows has done for his Ph.D. at Stanford University and include sophisticated 3D descent to approach flight path generation. Andy has successfully created a tunnel highway and flown it down to the approach. The concept is that once we have terrain data, we can generate a descent path to an instrument approach down to some height AGL, at some point of lat/long, heading in a desired direction.

Some synthetic vision ideas

The Synthetic Vision Display

- The presentation of terrain, and what should be in it, should be developed iteratively. There may be a need for the pilot to "personalize" his display. These two points compliment each other. Features may be added to the terrain display and then switched off or on for subjective testing by pilots for example, an artificial horizon overlay.

- The display size should be as large as possible to more closely mimic out-the-window viewing. HMDs can do this with aplomb.
- As many visual depth cues should be employed as possible without cluttering up the display.
- Should display hardware be head mounted, panel mounted, a HUD, a carry-on notebook, etc.? The answer may be dependent on the stage of development of the technology, the aircraft category and the political acceptance of technologies by the FAA and airline management.

DEMs (Digital Elevation Models)

- The accuracy and resolution of the DEMs are the two main factors of concern. Thirty arc second data is suitable for CFIT prevention. Accuracy can be vastly improved using programming techniques and manually editing the DEMs. Hopefully the '98 Shuttle flight will yield a worldwide accurate DEM. Computer power limits the use of ultra high-resolution DEMs.
- Multiple resolution DEMs offer great flexibility. On final approach and landing use 6" DEMs. At low levels, say below 3,000' AGL use 15" DEMs. Above 3,000' or in Victor airways use 30" DEMs, above 10,000' 1' DEM, above 18,000' 5' DEM. With thinner DEM resolution the rendering range increases, appropriate for the higher altitude. Five minute DEMs can be used to render the planet for a viewpoint from space.

Computing Power and Software Tools

- As of January 1998, we have enough computing power on Intel/Windows '95/NT platforms to do a good job with synthetic vision. Due to the increase in CPU power coming, with improved operating systems and video card power, we will be in excellent shape by the end of this year. In 1999 we will have 64 bit CPUs running at least four times faster than current technology.
- We are using Microsoft Direct3D in Free Flight where others are coding in Open G/L, the Silicon Graphics standard. There is little functional difference between these standards. We chose Direct3D because it appeared there would be wider hardware support for it in the market. This is true for now but Microsoft and Silicon Graphics have recently agreed to merge their programming instructions (APIs) so one program will support either standard.

FAA Certification

- This is a big one. The hardware and software technologies needed for synthetic vision exist now with the most common, off the shelf computer standards. We are looking forward to synthetic vision use in the cockpit. It needs to be programmed a bit more, integrated with an acceptable hardware platform, tested in the simulator, flight-tested and certified under the auspices of the FAA.

Airline Management Acceptance

- The commitment by corporate management to place their money and resources into deploying synthetic vision in the cockpits of their airplanes is a political matter. I believe this NASA Workshop, the commitments of the American Airline pilots union (APA), ALPA and IFALPA and others is building a consensus that will be unstoppable over the next several months in 1998. An airline pilot can make a tough case for synthetic vision simply by going on television with his daughter and letting the audience know he wants it to protect her with SV technology when she's flying on his airplane. Or a pilots union can threaten to strike. These are difficult for an audience or airline management to ignore.

The Future of Synthetic Vision

A cursory look at the future of synthetic vision promises:

- A "command" highway in the sky for navigation. It is a command roadway because it marks off the route of flight. This technology was researched extensively by George Hoover and proven workable. The highway is dynamic because it can change to adapt to different conditions. It may have some "intelligence" programmed into it for flexibility. The highway will allow the pilot to fly from takeoff, enroute, to a CAT III landing and taxi to his gate or parking spot.
- Traffic in the immediate area will be displayed and potential conflicts highlighted to alert the pilot. TCAS could be the data source. Current sensor technology offers alternate solutions.
- Weather will be presented in the synthetic vision space if it is hazardous. This data can be obtained from Wx radar, ground station sensors or satellites. The data uplinked from the ground via datalink or downlinked from satellites.
- Windshear will also be displayed in the synthetic vision space.
- Synthetic vision will be used in space navigation.
- There will be many, many more applications for this technology.

Jorj

Jorj Baker, President
Free Flight, Inc.

S22-06

Army/NASA Rotorcraft Division

RDEC

Synthetic/Enhanced Vision for Rotorcraft

Synthetic/Enhanced Vision Systems for Rotorcraft
Type-Specific Issues, Requirements, and Technical Challenges

William S Hindson
Chief, Flight Control and Cockpit Integration Branch
Army/NASA Rotorcraft Division
NASA Ames Research Center

James M Daum
Human Factors Engineer
Boeing Helicopters

Presented at Synthetic Vision Workshop Two
NASA Aviation Safety Program 27-29 Jan 98

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Army/NASA Rotorcraft Division

RDEC

Synthetic/Enhanced Vision for Rotorcraft

Objective
Accident Statistics
Rotorcraft Issues
Technical Challenges and Requirements
Potential solutions
Prior NASA research
Current NRTC/Boeing Activities

2

Army/NASA Rotorcraft Division

RDEC

Synthetic/Enhanced Vision for Rotorcraft

Objective

Provide lowcost systems and procedures to:

permit safe recovery from inadvertent entry into IMC in a near terrain environment

enhance safety of high workload rotorcraft missions operating near terrain and close to obstacles

3

Army/NASA Rotorcraft Division

RDEC

Synthetic/Enhanced Vision for Rotorcraft

Accident Statistics

from NTSB Database for Rotorcraft Accidents

Of 1165 investigations reported since 199[illegible]
entry into IMC a factor in 26 (2.2%)

NTSB Codes for VFR Flt into IMC:
attempted / inadvertent / continued / intentional / initiated

5.4% of fatal accidents, 10.5% of fatalities

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Army/NASA Rotorcraft Division

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Issues Associated with Inadvertent IMC

Rotorcraft have a greater vulnerability

Likelihood of operating near terrain in poor visibility is greater
- Rotorcraft missions are usually low altitude
- Class G airspace weather minima are permissive
- IFR infrastructure / regulations often a disincentive

Aircraft control in IMC is more demanding
- Stability is lacking - both hands and feet typically occupied
- Maintaining coordinated flight is more difficult
- Motion cues are confusing
- Vibration, rotor flicker can be distracting
- Instrument proficiency often deficient
- Recovery from unusual attitudes requires caution

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Army/NASA Rotorcraft Division

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Issues Associated with Inadvertent IMC

Rotorcraft have a greater vulnerability

Rotorcraft missions can be highly demanding (eg EMS)
- Single pilot, night, unfamiliar terrain
- Flight conditions include cruise, creep, or hover
- Propensity for drift into terrain or obstacles
  alleviated by good visual cues, vehicle stabilization
- Visual obscuration due to local flow field, downwash
- Need for "proximity warning" even with good visual cues

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Technical Challenges

Operating environments are random, unstructured (eg EMS)

>>> wide area databases required

Low and slow missions demand greater scene detail and database resolution to support pilot orientation and control

>>> stretches database generation, storage, uploading, updating, processing & rendering requirements

Proximity to surface and obstacles inherent with low altitude missions and permitted by Class G airspace weather minima

>>> fusion of stored database with vision aiding sensors needed to assure safety

Army/NASA Rotorcraft Division

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Technical Challenges

Low cost, low weight, small size is paramount

Registration requirements may exceed capability of most helicopters eg GPS positioning and heading accuracy

Vision aiding sensor requires high field-of-view (regard) and high resolution

Capability to detect wires highly desirable

All-azimuth capability highly desirable

Automobile technology could apply (proximity sensor)

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Potential Solutions / Current Programs

Terrain Awareness Laptop-based Products

shortcomings are low resolution databases, mounting, need for a free hand to operate

Enhanced GPWS

costly, tailored to higher speed aircraft always in coordinated flight

Low Cost vision aids

scanning radar altimeter

Automobile Technology

94GHz proximity detection

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Prior Research at NASA Ames

Automated Nap-of-the-Earth (ANOE) Program 1990-1996

Objectives:

Develop and validate in flight test technologies for conducting terrain following / terrain avoidance flight in military rotorcraft

Flight test sensors for obstacle detection and develop associated pilot displays and cueing for obstacle avoidance in nap-of the-Earth flight

Develop automation pilot aids for enhanced safety and mission effectiveness in nap-of-the-Earth flight

Example Results:

Path generation and display guidance for TF/TA flight

Scanning radar altimeter and associated grid world display

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NRTC

Synthetic/Enhanced Vision for Rotorcraft

PROJECT: 97-9.1(2)
HELICOPTER OPERATIONS / APPROACH INVESTIGATION

Boeing/NRTC Synthetic Vision System Activities

- ***Rotorcraft Approach by Visually Enhanced Navigation***
  - Navigate using a high resolution 3D data base during terminal approaches in near zero visibility
  - RAVEN utilizes Differential GPS for precise geolocation in a synthetically generated scene
  - The ultimate goal is to develop an affordable commercial product that improves operational safety
  - Optimize SV for tiltrotors and rotorcraft

BOEING

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NRTC

Synthetic/Enhanced Vision for Rotorcraft

PROJECT: 97-9.1(2)
HELICOPTER OPERATIONS / APPROACH INVESTIGATION

WHY TILTROTOR / ROTORCRAFT SV

- Move tiltrotors and rotorcraft out of flow of fixed wing traffic.
  - Increased departures and arrivals for air carriers
  - Improved efficiency of tiltrotor with direct routing below fixed-wing airspace
- Tiltrotor approaches in terminal areas to precision approach minimums without the high cost of ILS equipment
- Provide ability to operate in low visibility at low altitude to unimproved sites
- Possibility to operate above obstacles in IMC with reference to synthetic terrain

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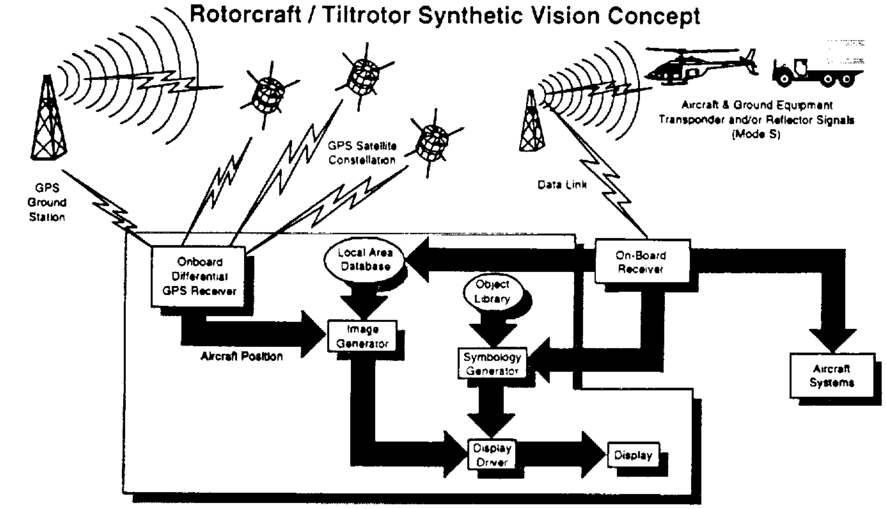
NRTC

Synthetic/Enhanced Vision for Rotorcraft

PROJECT: 97-9.1(2)
HELICOPTER
OPERATIONS / APPROACH
INVESTIGATION

Rotorcraft / Tiltrotor Synthetic Vision Concept



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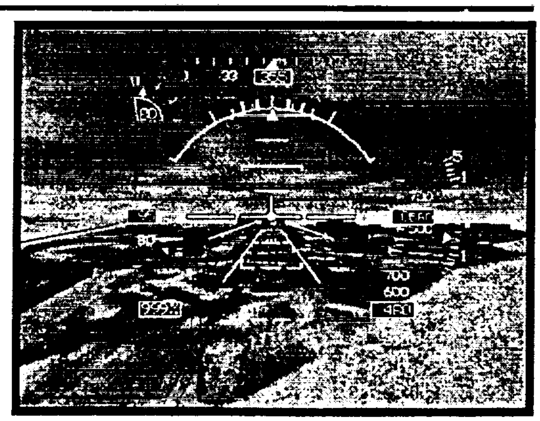
NRTC

Synthetic/Enhanced Vision for Rotorcraft

PROJECT: 97-9.1(2)
HELICOPTER
OPERATIONS / APPROACH
INVESTIGATION

- **Synthetic Vision Simulation**
  - V-22 Tiltrotor Simulator
  - Terminal area/ urban database
  - Enhanced copy of urban database used as SV scene
  - Study of display, database, & symbology requirements



Synthetic Scene with Symbology Overlay

  - Course-guidance "hoops" [aka pathway in the sky] displayed in synthetic vision
  - Synthetic Vision video scaled to match existing V-22 symbology & MFD's

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SINGLE SCAN

S22-03

NASA Aviation Safety Program

Workshop on Synthetic/Enhanced Vision Display Systems

Session: Advanced Vision and Sensor Technology

January 27-29, 1998

Langley Research Center
Hampton, Virginia
23681

Langley Research Center
Flight Electronics and Technology Division

ERB.198.012.A

Workshop on Synthetic Vision

- **Goals of Synthetic Vision Effort**
  - Eliminate CFIT for transport operations
  - Provide affordable CFIT and Loss of Control avoidance for GA
  - Provide stepping stone for future all-visibility/all runway manual operation

- **Purpose of Workshops**
  - Identify key technical issues/hurdles
  - Gov't/Industry and Industry/Industry interchange
  - Identify appropriate NASA/Government roles
  - Allow NASA to intelligently structure NRA

- **The Synthetic Vision project will be one of the AvSP's most powerful opportunities for safety benefits as well as one of the most technically and publicly exciting**
  - NASA/FAA will work very hard to get it right
  - We ask for industry's aggressive participation and support

ERB.198.023.A

Workshop on Synthetic Vision

- **Confluence of Technologies**
  - GPS
  - Data Storage
  - Digital Processing
  - Glass Displays

- **Sensor Technology**
  - Faces very difficult technical hurdles
    - Must compete with an optical disc for cost, complexity, total coverage all condition certifiability, affordable GA application, etc.
  - Program resources not available for both a sensor development program and data base driven development program
  - If a sensor-based system is available that meets CFIT/Loss of Control safety benefit requirements, the AvSP would certainly be interested in evaluating it
    - Need to clearly identify system requirements up front

ERB.198.024.A

Session: Advanced Vision and Sensor Technology

Workshop Objective: Discuss topics in synthetic vision (SV) element of the NASA Aviation Safety program and to develop participation in development process for Aviation Safety

Approach: Technology applications for low-end general aviation, high-end general aviation aircraft, and commercial transports

Emphasis: Cost-effective use of synthetic vision displays, worldwide terrain data bases, and GPS navigation <u>to eliminate visibility-induced errors for all aircraft</u>

Pre-condition: Currently a sensors development thrust is not envisioned to be part of the program

FRB 198 015 A

NASA Aviation Safety Program
Synthetic Vision and Sensor Technology

NASA Research Announcement (NRA) For SV Technology

Low-cost SV Display Technology ⇒ **Low-end Thrust**
- General Aviation in VMC to enable safe landing or transit to VMC in the event of encounter of IMC conditions

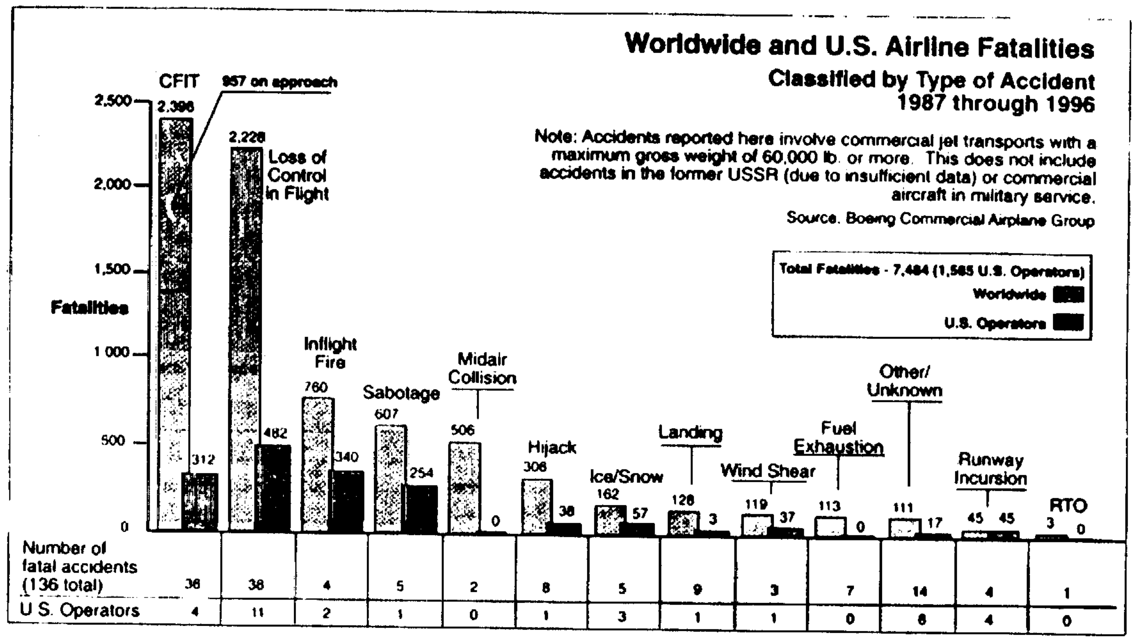
Higher-cost SV Display Technology ⇒ **High-end Thrust**
- Enhance situation awareness and tactical flight path management in low visibility conditions

ERB 198 014 A

Steady Improvement in Airline Safety Due To Sophisticated Sensors at Airports and on Jets

(Source: Wall Street Journal, Aug. 11,1997)

Large percentage of CFIT accidents during approach and landing



Reductions in crashes due to wind shear and midair collisions due to sophisticated sensors at airports and on jets

ERB 198 019 A

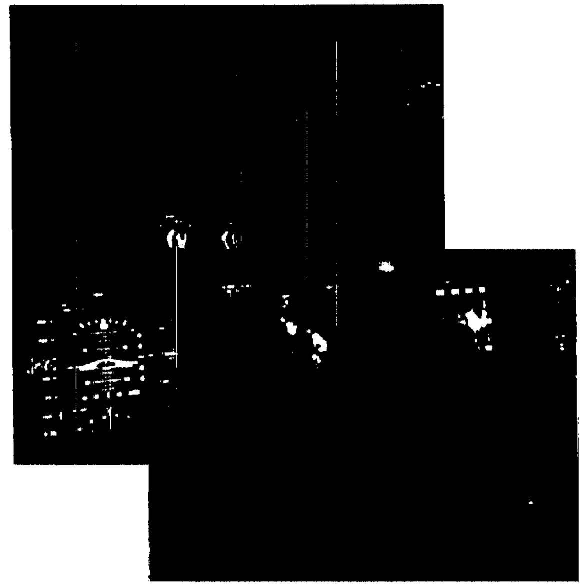
Safety of Nonprecision Approaches Examined

Worldwide Commercial Jet Transport Accidents, by Phase of Operation, 1958-95

Phase	Number of Accidents
Landing	586
Approach	271
Takeoff	265
Climb	104
Cruise	82
Taxi	80
Descent	47
Go-around	26
Ground Event	16
Engine Start	4
Parked	2

Note: An accident may involve more than one phase of operation

Source: Flight Safety Foundation/McDonnell Douglas Corp./Jeppesen Sanderson Inc.



Nondirectional Radio Beacon (NDB) Approaches by World Region

Region	Number of NDA Approaches
Africa	60
Canada	237
Eastern Europe	177
Europe	287
Latin America	54
Middle East	68
Pacific	71
South America	200
South Pacific	81
United States	1,578
Total	2,813

Source: Flight Safety Foundation/McDonnell Douglas Corp./Jeppesen Sanderson Inc.

- Risk of an accident is five times higher for commercial airline aircraft flying a nonprecision approach (1996 Flight Safety Foundation Report)

- Additional research found that nonprecision approaches are associated with 60% of the commercial airline crashes worldwide which are due to controlled flight in terrain (CFIT)

- Combination of poorly designed nonprecision approach, inadequate equipment and inclement weather led to CFIT crash of USAF CT-43A (April 1996)

Current Approach to Avoid Airline Accidents Attributed to Controlled Flight Into Terrain (CFIT)

A6 THE WALL STREET JOURNAL TUESDAY, DECEMBER 16, 1997

U.S. Airlines Plan Warning Systems For 4,300 Aircraft

By Jeff Cole
And Andy Pasztor
Staff Reporters of The Wall Street Journal

WASHINGTON – U.S. airlines will voluntarily install advance-warning systems on about 4,300 passenger and cargo planes to help keep the aircraft from crashing into mountains and other terrain.

The $400 million move, announced by the Air Transport Association and federal regulators yesterday, broadens and could accelerate installations begun more than a year ago by AMR Corp.'s American Airlines unit, UAL Corp.'s United Airlines unit, Alaska Airlines and Delta Air Lines.

About 175 planes have been fitted with the new systems, which use signals from global-positioning satellites and digital maps of terrain or airports. The systems, made by AlliedSignal Inc. and the only ones certified so far by the Federal Aviation Administration, greatly increase the warning time and detail of information to a pilot whose plane is getting dangerously close to terrain. By 2003, the next 4,300 aircraft are to be fitted with the system, accounting for 68% of jets in the U.S. commercial fleet.

Carol Hallett, the ATA's president, said the move should "largely eliminate" collisions with terrain by U.S. commercial transports. It was applauded by the FAA, which plans to make the installations mandatory during 1998, to ensure that non-ATA carriers make the changes. ATA members account for 95% of U.S. commercial-transport traffic.

Older versions of "terrain awareness" systems have been widely installed in large commercial jetliners. But they have failed in two thirds of accidents in which a plane flies into the ground even though it is otherwise functioning normally. During the past 10 years, about 36 large planes from Western nations were involved in such accidents, according to aircraft maker Boeing Co. and airlines.

The new systems cost $70,000 to $115,000 each, depending on the aircraft type, and they have been certified for installation in six jet types. The new systems expand warning time to as much as two minutes from as little as 10 seconds.

Ed Soliday, a vice president for safety at United Airlines, said last week that the new systems are "essential and we need to get on with it."

- U.S. airlines voluntarily install advance-warning systems on 4,300 passenger and cargo airlines
- AMR Corp./American Airlines
  UAL Corp./United Airlines
  Alaska Airlines
  Delta Airlines
- GPS and digital maps of terrain or airports
- Systems developed by Allied Signal Inc.
- Older versions of "terrain-awareness" systems have failed in two-thirds of CFIT accidents
- New systems increase warning time to as much as two minutes at cost $70K to $115K each

ERB 198 018 A

Advantages Using Advanced Sensor Technology for Airline Operations and Aviation Safety

- New sensors capable of imaging the forward scene in low visibility conditions have been developed by the U.S. industry
- Combined with navigational sensors and displays, these enhanced vision systems allow a pilot to land, roll, taxi, and take-of during low visibility conditions
- Obstacle avoidance capability is provided by EVS
- EVS supports NASA's Aviation Safety goal to triple capacity under adverse weather conditions in less than 10 years
- Cost/benefit advantages to U.S. taxpayer have been established
- Early burden pushing the development of enabling technologies has already been borne by Industry (with support from DoD)
- NASA's role is needed to integrate these enabling technologies and demonstrate/evaluate performance to meet program objectives

ERB 198.020 A

Workshop on Synthetic/Enhanced Vision Display Systems

Session: Advanced Vision and Sensor Technology

Presentations

10:05 - 10:20	Introductory Comments for Presentations and Subsequent Panel Discussion	Tom Campbell, NASA LaRC
10:25 - 10:50	(Active) Millimeter Wave Enhanced Vision System (EVS)	Thomas Henry, Lear Astronics Corporation (LCS)
10:55 - 11:20	(Passive) Millimeter Wave Imaging Sensor System	Steve Fornaca, TRW
11:25 - 11:50	FogEye Ultraviolet Sensor SystemLunch	Vic Norris, Norris Electro Optical Systems
11:50 - 12:50	Lunch	
12:50 - 1:15	Multi-Fusion Sensor Technology	Peter Symosek, Honeywell
1:20 - 1:45	Forward-Looking Infrared Sensor Technology	Dick Zeylmaker, FLIR Systems, Inc.
1:50 - 2:15	Sensor Fusion for Human Vision	Eli Peli, NASA Ames
2:15 - 2:30	Break	
2:30 - 3:45	Panel Session	

Omit to P. 344

NASA Aviation Safety Program

Synthetic/Enhanced Vision Workshop

Session: Advanced Vision and Sensor Technology

Panel Session Participants

Session Chairman: Thomas G. Campbell, NASA Langley

Sensors

Merit Shoucri, TRW
Dutch Nielson, Lear Astronics
Dick Zeylmaker, FLIR Systems
Richard Burne, Allied Signal Corp.
Vic Norris, Electro Optical Systems

Sensor Fusion

Peter Symosek, Honeywell Technology Center

Flight Operations

Mike Frank, United Airlines
Paul R. Leckman, Boeing Commercial Airplane Group
Mike Norman, Boeing - Long Beach
Alberto Ortiz, Boeing, Long Beach
Malcolm Burgess, Research Triangle Institute

Data Bases

Ronald Bolton, Aeronautical Chart Division
Office of Aeronautical Charting and Cartography (National Ocean Service)

Questionnaire Form

NASA Aviation Safety Program

January 27-29, 1998

Workshop on Synthetic/Enhanced Vision Display Systems

Panel Session: Advanced Vision and Sensor Technology Role

Name ______________________________

Organization ______________________________

Telephone/Fax/E-mail Address ______________________________

Question: ______________________________

____

____

____

Technology category for question addressed: (check box)

☐	**Sensors**	☐	**Sensor Fusion**	☐	**Flight Operations**	☐	**Data Bases**

Committee Action

Question assigned to: ______________________________

Follow-up required: ______________________________

ERB.198.021.A

LEAR ASTRONICS®

NASA Safety Program
Synthetic Vision Panel

29 Jan 98

Topic:

Sensor Application Safety

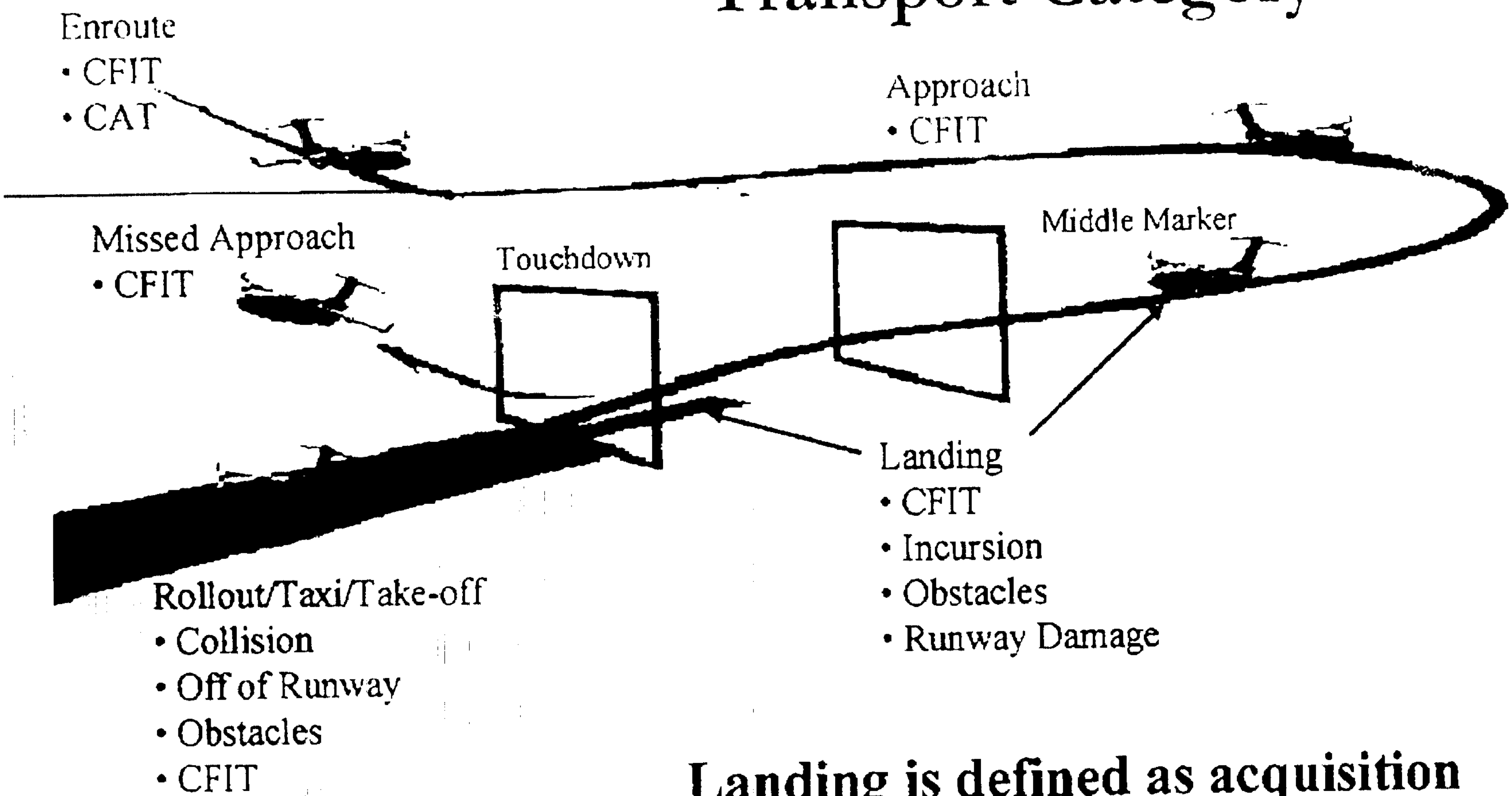
SINGLE SCAN
523-03

LEAR ASTRONICS®

Customer Future Business Goals

- **Increase Revenue**
  - Larger more modern fleets
  - Modernization of current fleet
  - Route and global expansion
  - Customer Satisfaction
- **Safety**
  - Better training
  - No safety Incidents
- **Operations**
  - Free Flight
  - Increased airport throughput
  - All weather operations

Clarification of NASA Program Synthetic Vision Focus Transport Category



Landing is defined as acquisition of glideslope at middle marker

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Future Safety Issues

- **Increased air traffic**
- **Greater ATC congestion**
  - In flight
  - At airports
- **Lack of infrastructure**
  - Instrumentation

	US	Europe	Asia	S.A.	Canada	Iceland	Moscow
✓ Cat II	80	75	6	2	7	1	2
✓ Cat III	43	52	0	0	0	0	0
✓ 700' RVR	4	35	0	0	0	0	0

  - Cat III Lighting/Markers
    - ✓ $ 600,000 to potentially greater then $2.6M/runway
    - ✓ Runway out of service
    - ✓ Continuing maintenance costs

LEAR ASTRONICS®

What are the Real Costs

- **Costs must consider**
  - Procurement
  - Installation
  - Certification (if a new product)
  - Maintenance
  - Training
  - Sustainment costs
    - ✓ Updating
    - ✓ Recertification
    - ✓ Distribution
    - ✓ Management

Not just $5,000 dollars for a CD

LEAR ASTRONICS®

Where are Airlines Going

- **Growth of EVS:**
  - Alaska (stroke)
  - Southwest (stroke)
  - Alitalia (raster capable)
  - Delta (raster capability)
  - American Airlines (raster capability)

Others Will Quickly Follow

With free flight, head up displays and sensors are a logical next step.

Sensors can augment CFIT avoidance, can aid in safe landings, detect obstacles, incursions in low visibility while reducing infrastructure costs

LEAR ASTRONICS®

Civil and Military Performance Validation

✈ Dissimilar aircraft architecture performance validation

USAF Speckled Trout

- Military/Digital/Glass Cockpit
- DGPS operation with imaging sensors
- Worldwide data collection (Approach/Light/Runway environments)
- Military [users] assessment
- Military operating criteria

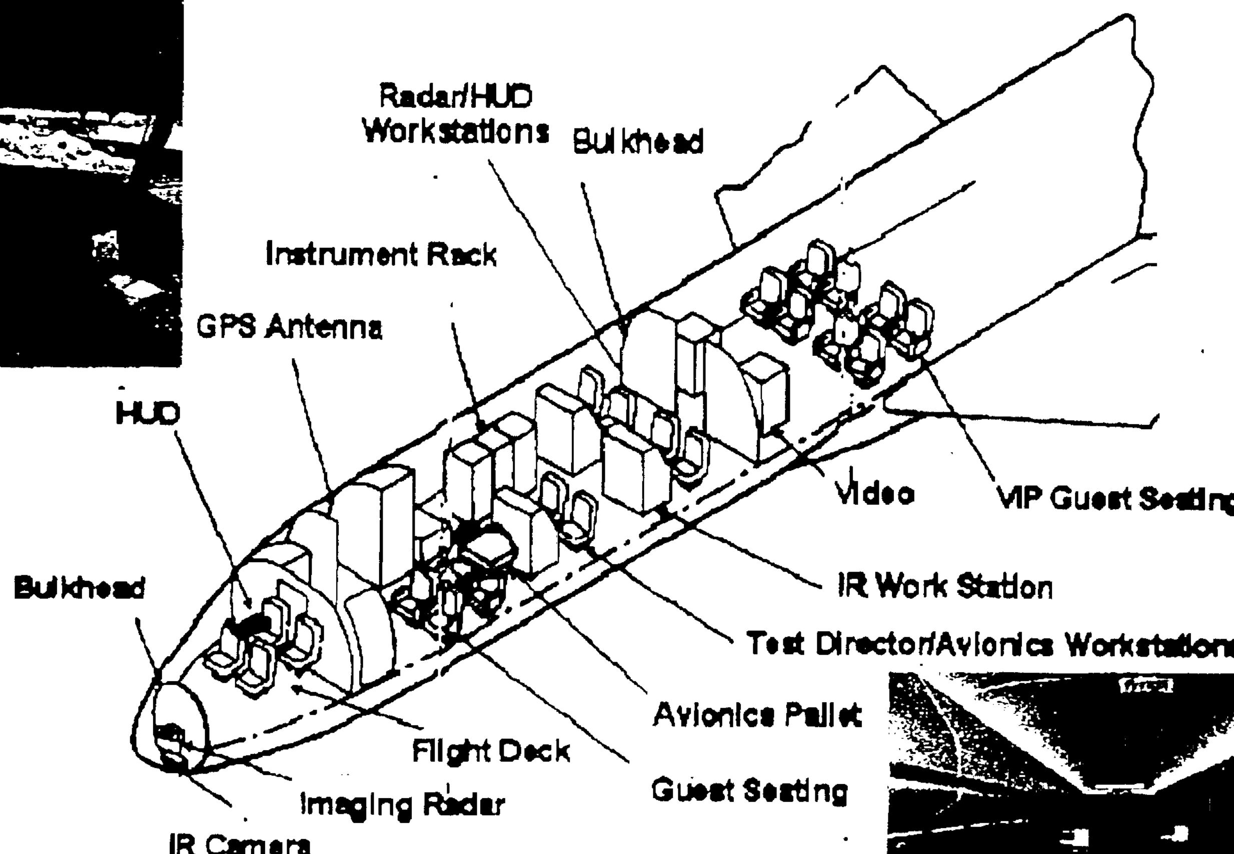
United B727

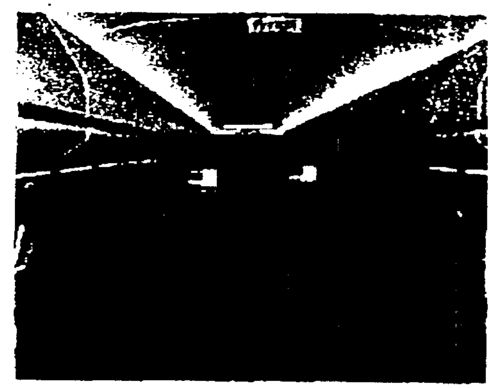
- Commercial/Analog
- Civil (FAA/JAA) assessment
- Commercial [users] assessment
- Commercial operating criteria

A0439

LEAR ASTRONICS®

B727 Instrumentation





LEAR ASTRONICS®

What is the Real Sensor Performance

- Many opinions expressed - on what facts?
- Who has participated in Lear's ALG program, with over 300 hours of flight test, including operations in IMC.
- No one in NASA knows where Lear plans to take the radar technology and the corresponding enhanced performance in the next few years.
- Lear is now under contract, effective 20 January 1997, to complete a 15 month flight test on a AMC C130 H3 to both AMC and AFSOC operational objectives.

LEAR ASTRONICS®

Detailed Requirements

C-130 Test

- Assess pilot's ability to fly approved instrument approach procedures and land in IMC using the ALG HUD, in both day and night conditions, up to full crosswind limitations of the C-130 aircraft.
- Assess the pilot's ability to fly SCA/ARA procedures and land in IMC using the ALG HUD, in both day and night conditions, up to the full crosswind limitations of the C-130 aircraft.
- Assess the pilot's ability to fly SCA/ARA procedures in night IMC and transition to a NVG landing using the HUD up to the full crosswind limitation of the C-130 aircraft.
- Verify the ability of the system to operate in varying weather conditions, I.e., fog, snow, rain, smoke, blowing sand, sleet, icing, etc.
- Assess the pilot's ability to taxi, takeoff, land, and rollout in day and night IMC on different airfield surfaces to include in order of priority concrete, asphalt, dirt, lakebed, sand, grass and PSP.
- Assess the degree of enhancement provided by radar reflectors and/or other aids (to be defined) in outlining unmarked runways.
- Assess the capability to identify runway incursions.

LEAR ASTRONICS®

Bottom Line

- How are sensor decisions made without an opportunity to be judged on facts.
- Sensors can be of value in meeting safety while enhancing the revenue of the airlines.
- ROI justification will be required for airline procurement.
- A mix of sensors with fusion, be they two optical sensors, or a sensor and a map, may be the best solution if it can be made affordable.
- Meanwhile, Lear is moving to a low cost, reduced form factor design with the first generation of image enhancement.

San Francisco International Airport

300

Radar Video

OMIT THIS PAGE

San Francisco International Airport

200

Cat I DH

Radar

Video

THE SCHEPENS EYE RESEARCH INSTITUTE
An Affiliate of Harvard Medical School

Sensor Fusion for Human Vision

Eli Peli

Representing: NASA Ames

NASA ARC, POC:Al Ahumada
(650) 604-6257
al@vision.arc.nasa.gov

Synthetic Vision Workshop 2

NASA, Langley

omit this page

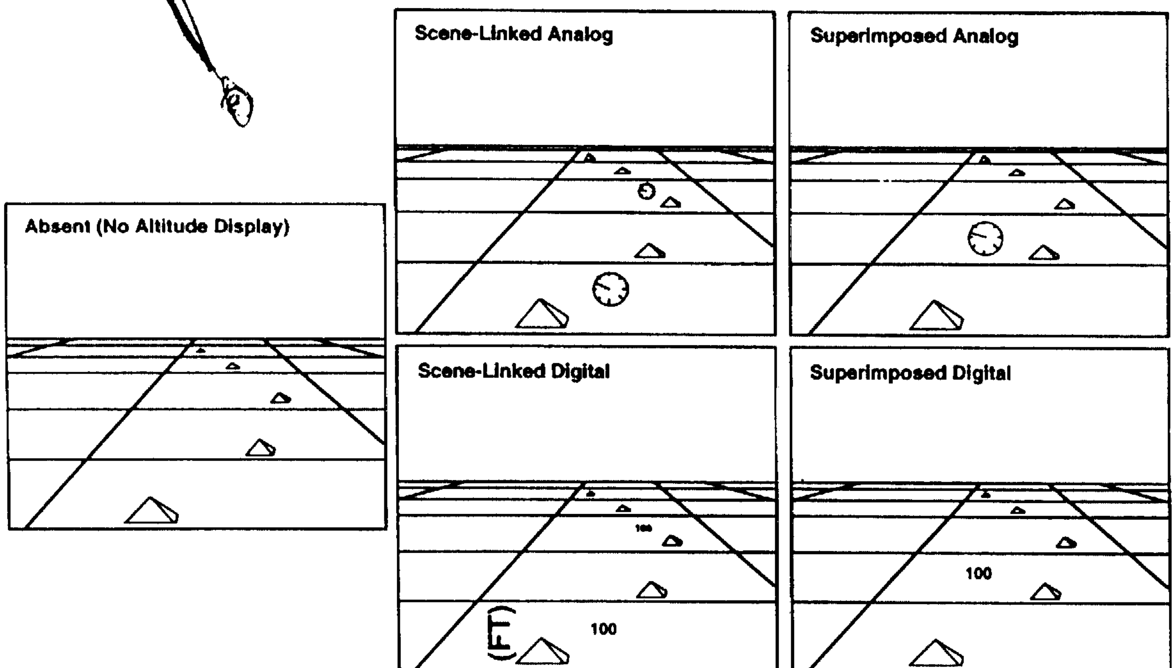
The Schepens Eye Research Institute, 20 Staniford Street, Boston, Massachusetts 02114
E.Mail: eli@vision.eri.harvard.edu

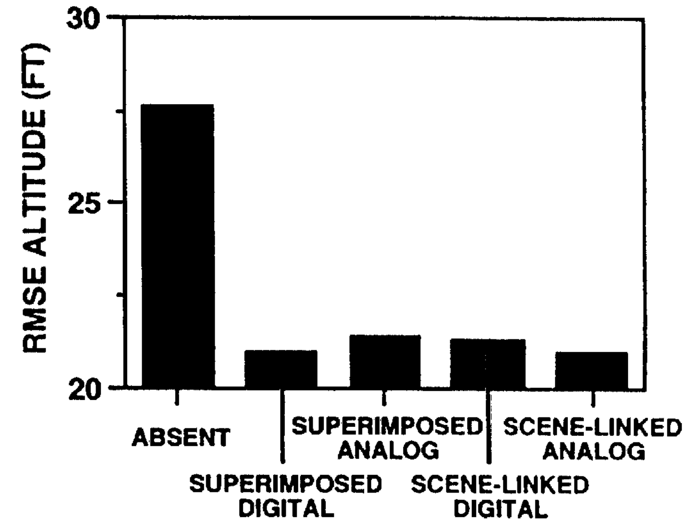
Phone: (617) 921-2597
FAX: (617) 921-0111

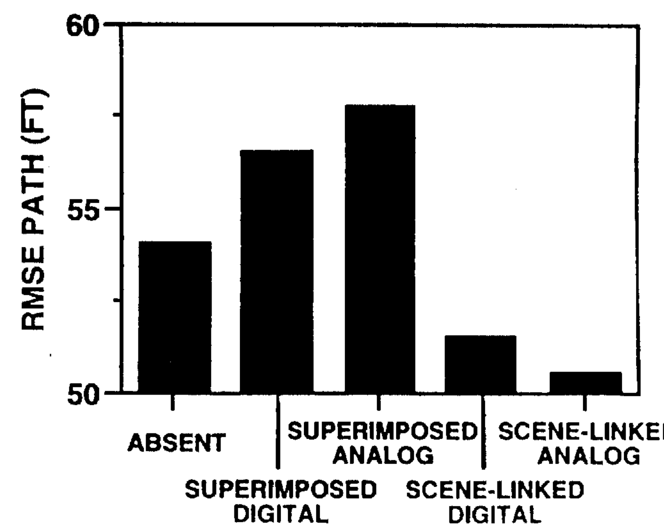
[redacted]

Scene-Linked Symbology

Foyle, McCann & Shelden (1995)



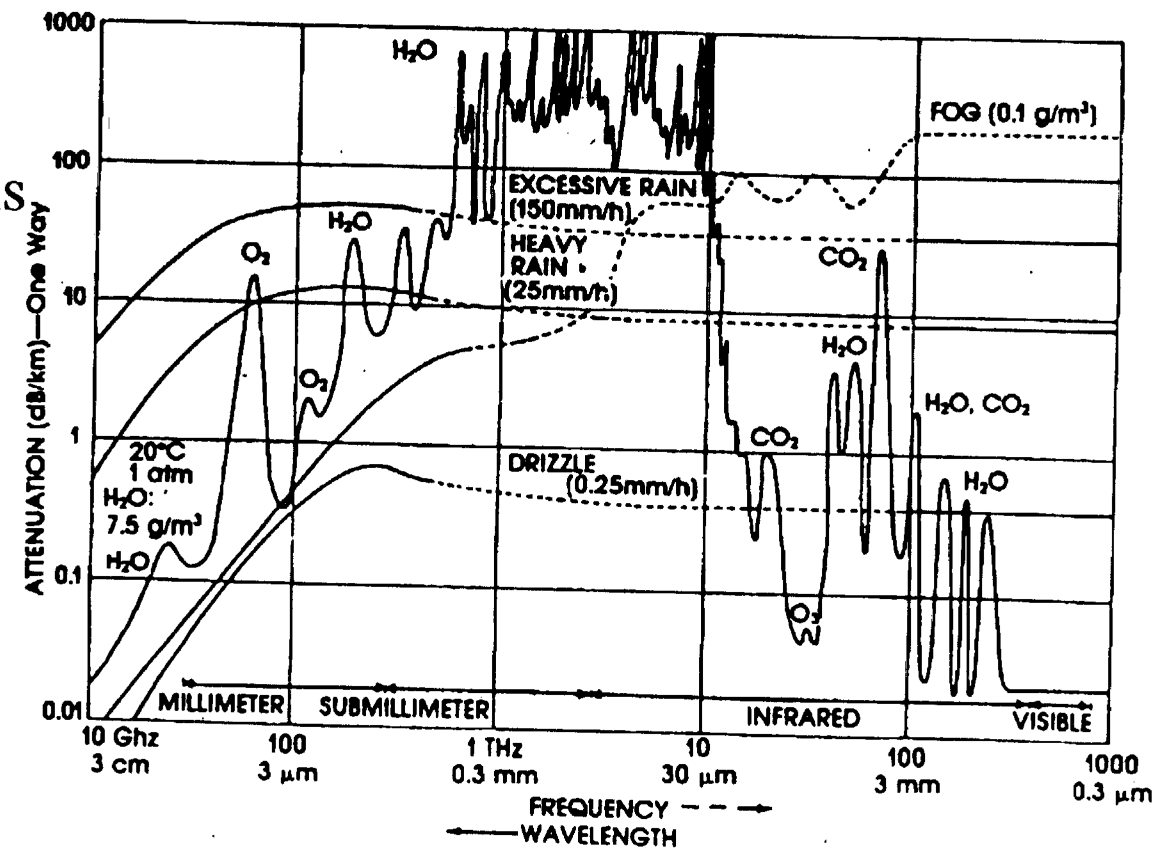




- Demonstrated attentional problems with superimposed symbology
- Scene-linked "virtual instruments" alleviates attentional problems

Multi-Sensor Approach

- Different sensors are useful in different conditions
- Independence of ground facilities



M.Pavel

Oregon Graduate Institute

S24-03

Verification

Sensor information has secondary role

- Use sensor fusion to verify position
- Use sensor fusion to confirm clear runway (detect hazard, runway incursions)
- Provide reassurance to the pilot...

Potential Sensors

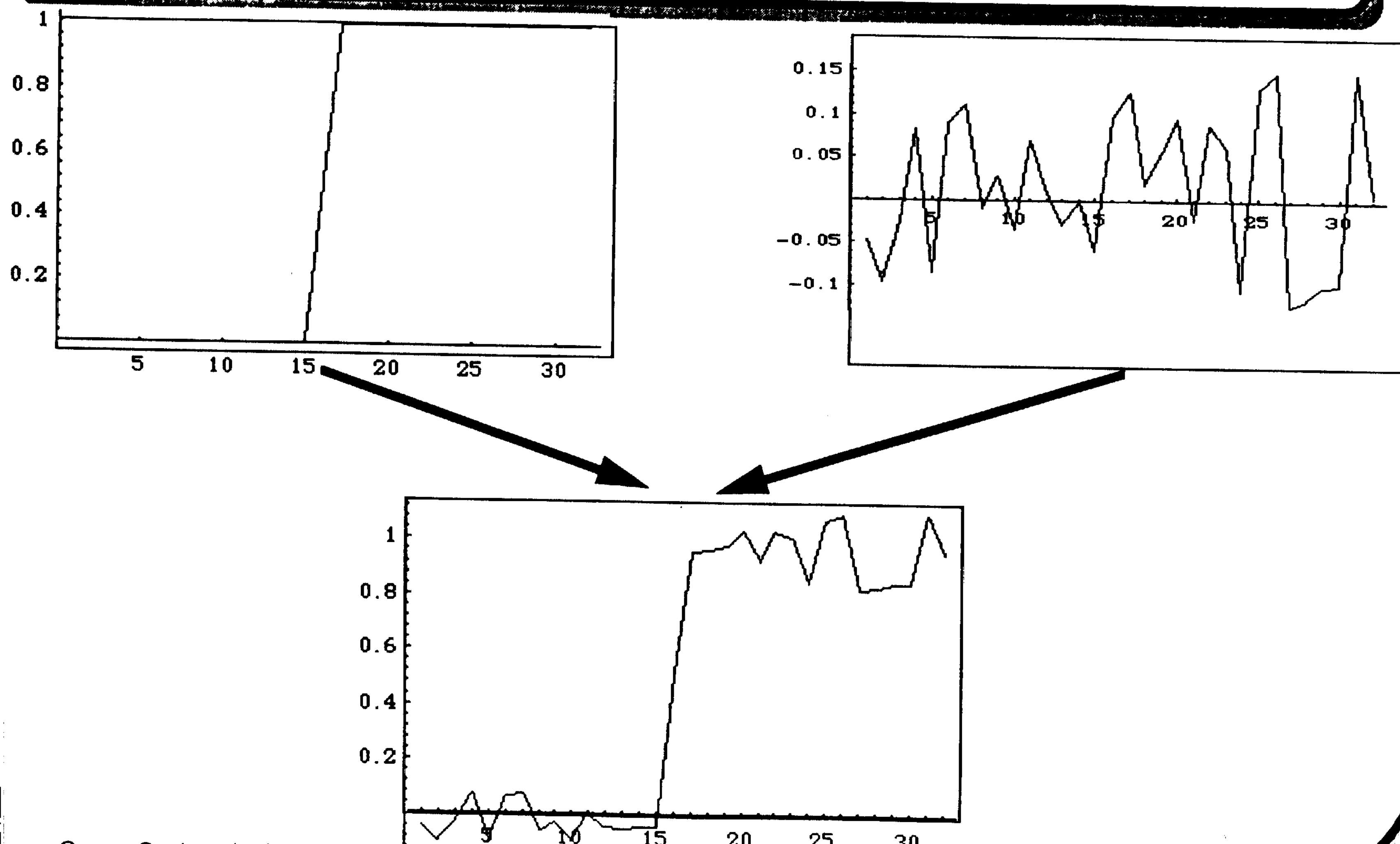
IR	Radar	Database
Thermal emissions	Reflections	Rendered airport scene
	Advantages	
No ambient illumination High contrast boundaries	Penetrates fog Measures distances	No imaging sensor Independent of weather
	Disadvantages	
Spurious/missing edges Polarity reversal/crossover Thermal shadows	Ambiguous projections Low spatial resolution Different from visual Slow frame rates	Missing mobile structures DB integrity problem No environmental conditions Viewpoint errors

Fusion Problems

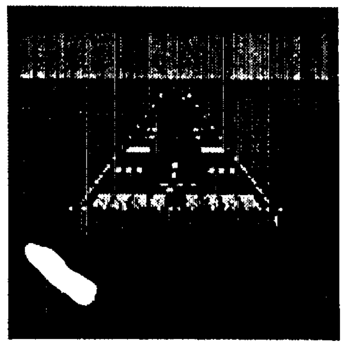
Possible Scenarios with Two Sensors

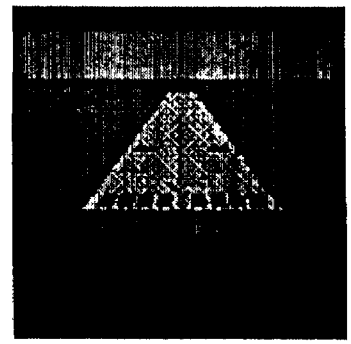
- **Signal (useful information) in one sensor only**
- **Information at different resolutions**
- **Complementary information in two or more sensors**
- **Correlated information, but noisy**
- **Signal in both, but with arbitrary polarity**
- **Imperfect registration**

One-Dimensional Example



Reverse Polarity





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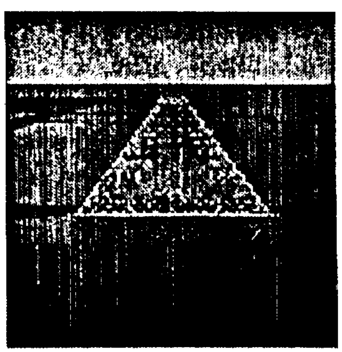
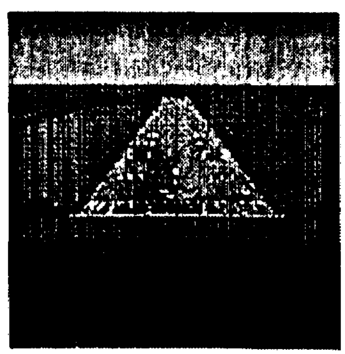
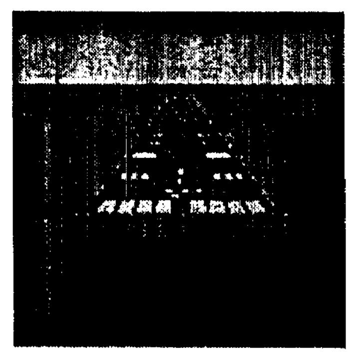


Smooth Max



Adapt.Corr



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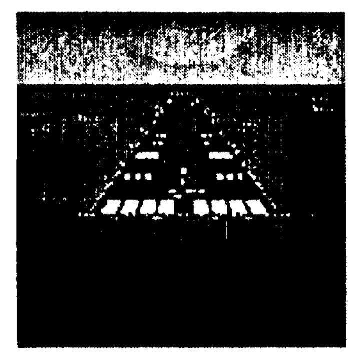
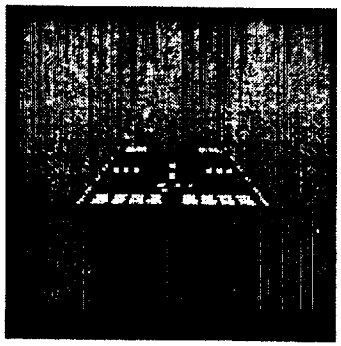


Low Visibility

TV - Fog



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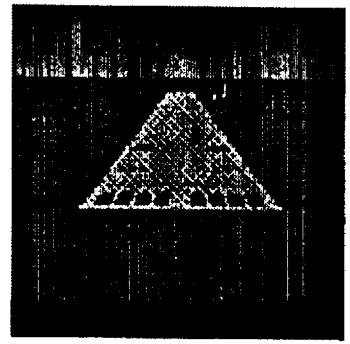
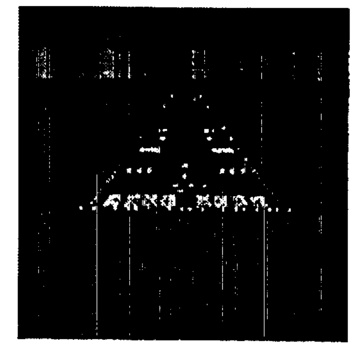


Database



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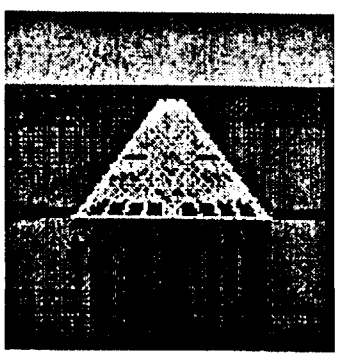

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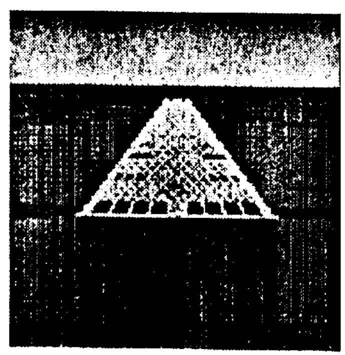

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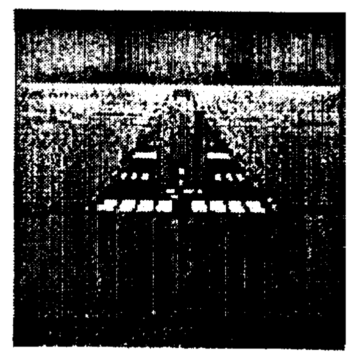

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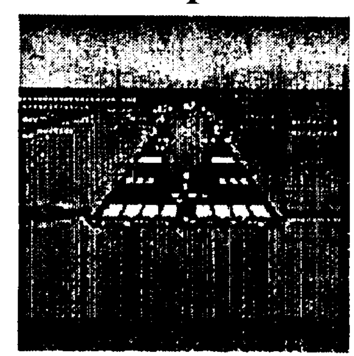


SINGLE SCAN

525-03

Visually-Based Multispectral Fusion

SBIR Phase I Atlantic Aerospace Electronics Corp.

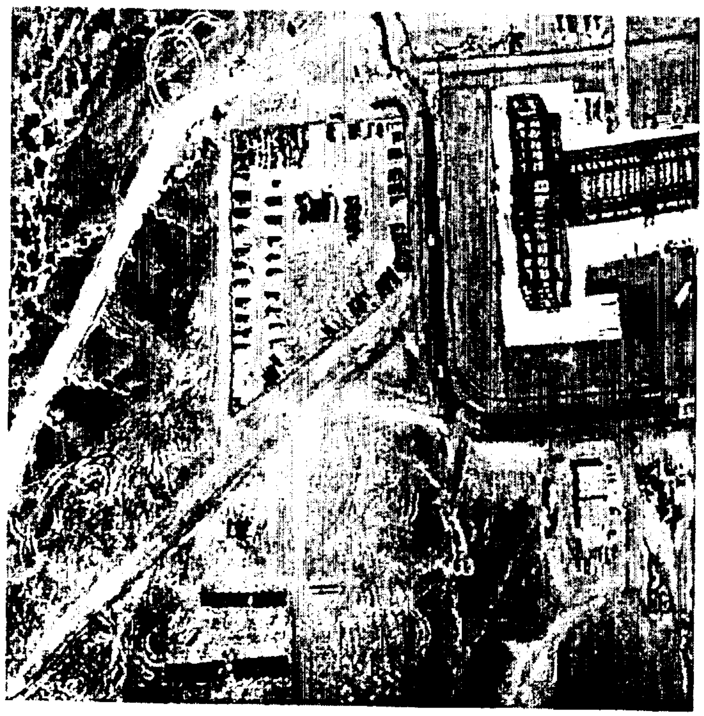
POC : T. Peli (781-890-4200)

Sponsored by ONR
in collaboration with Kip Krebs,
Naval Post Graduate School

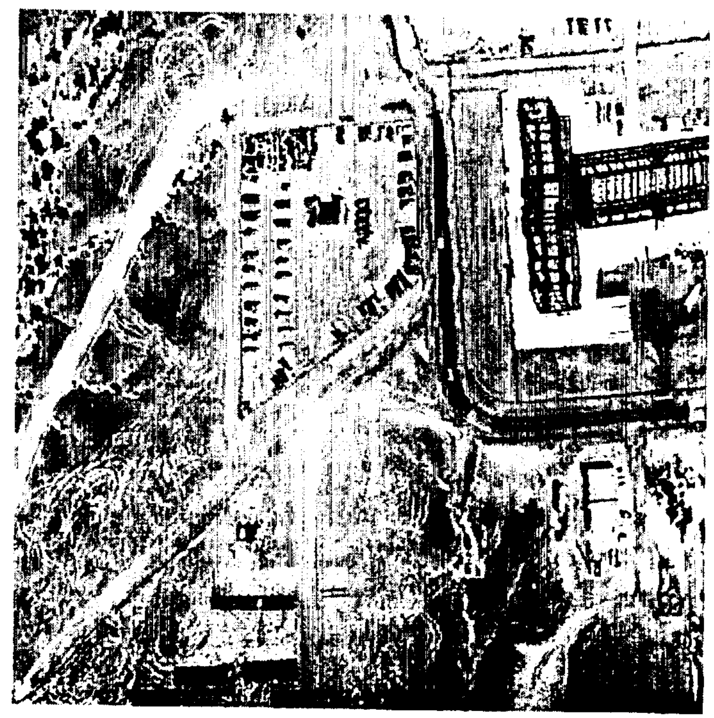
ATLANTIC AEROSPACE
ELECTRONICS CORPORATION

Visual Image

original



normalized



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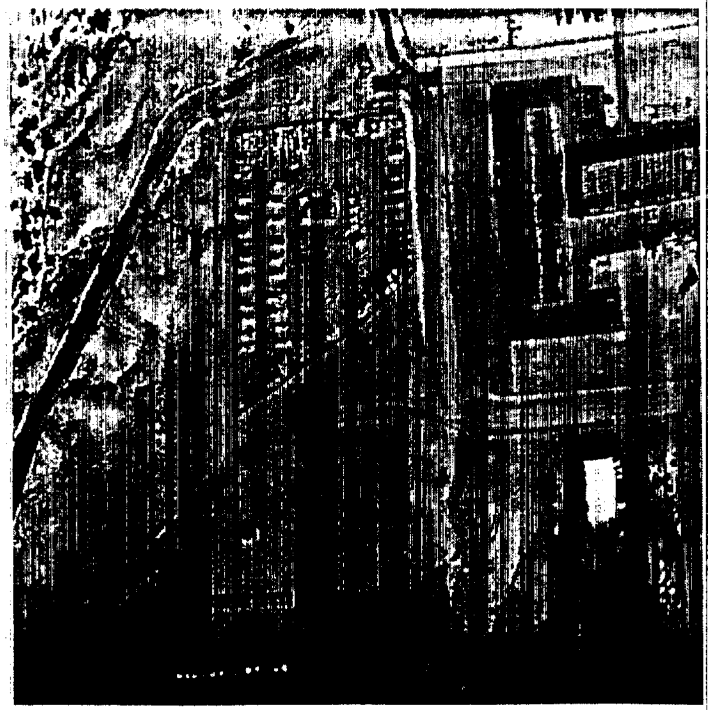
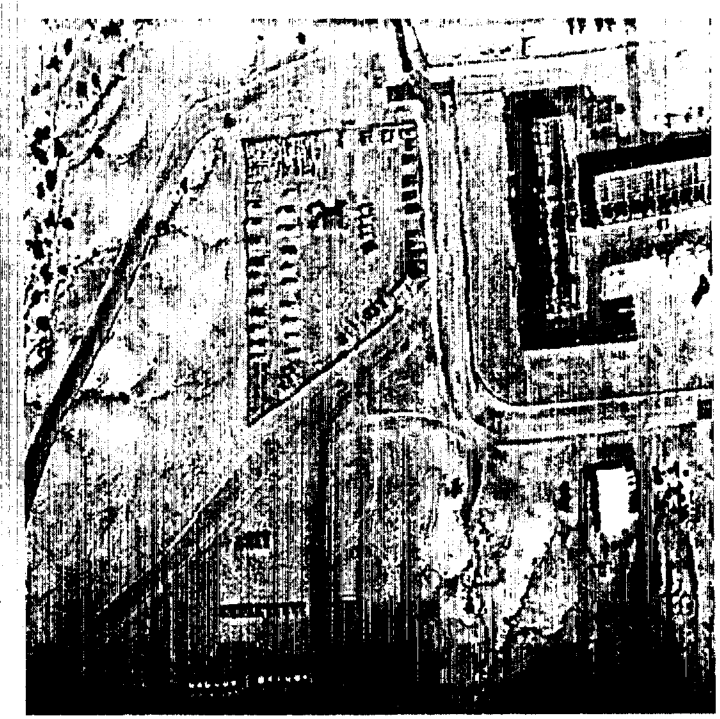
IR Image

original



normalized



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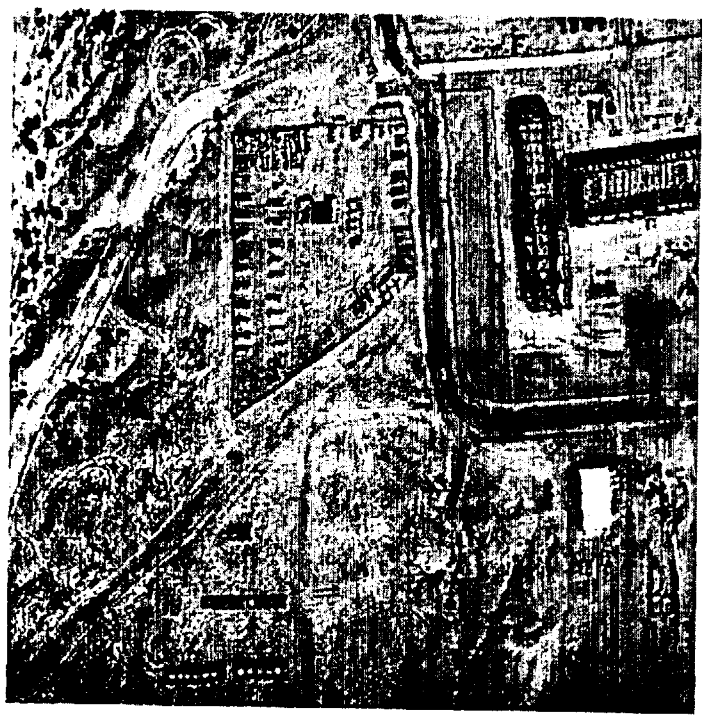
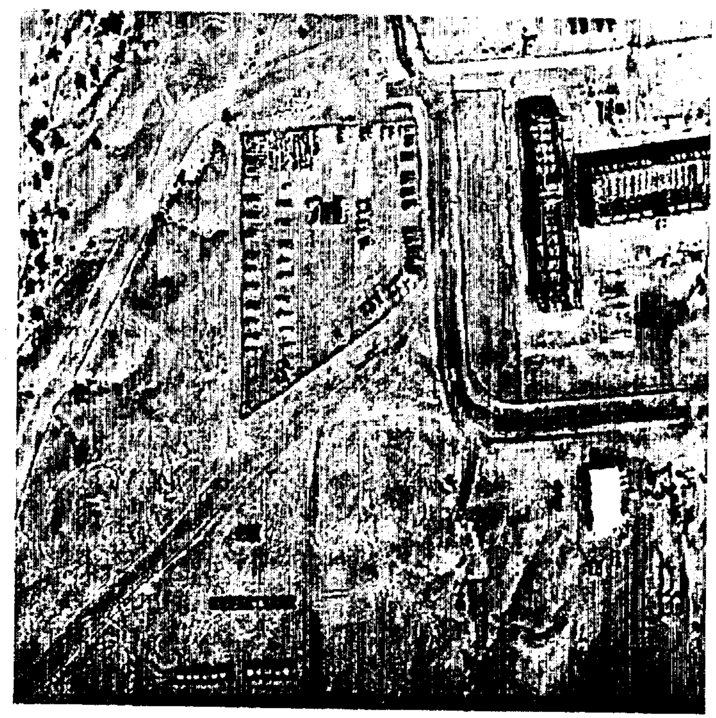
Fusion Method

amplitude-based



contrased-based



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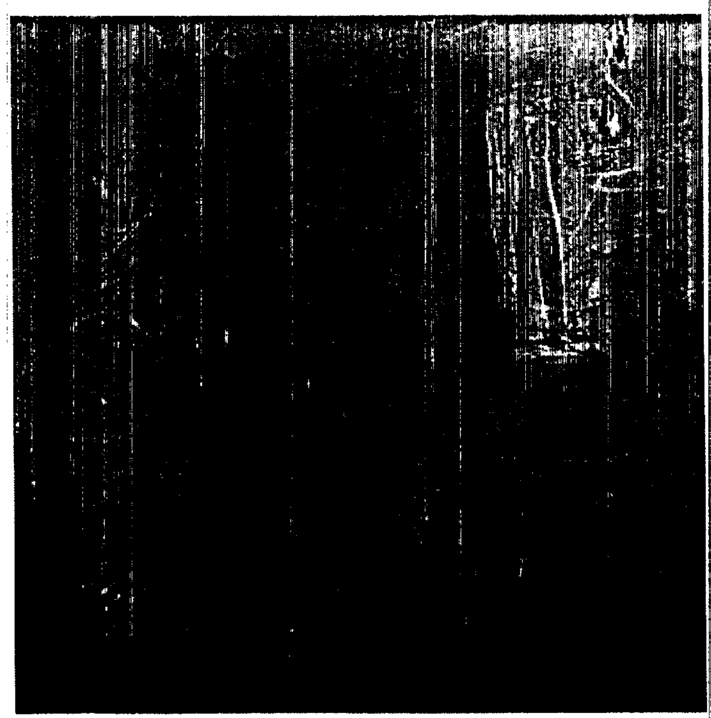
Difference Image (amplitude vs contrast)



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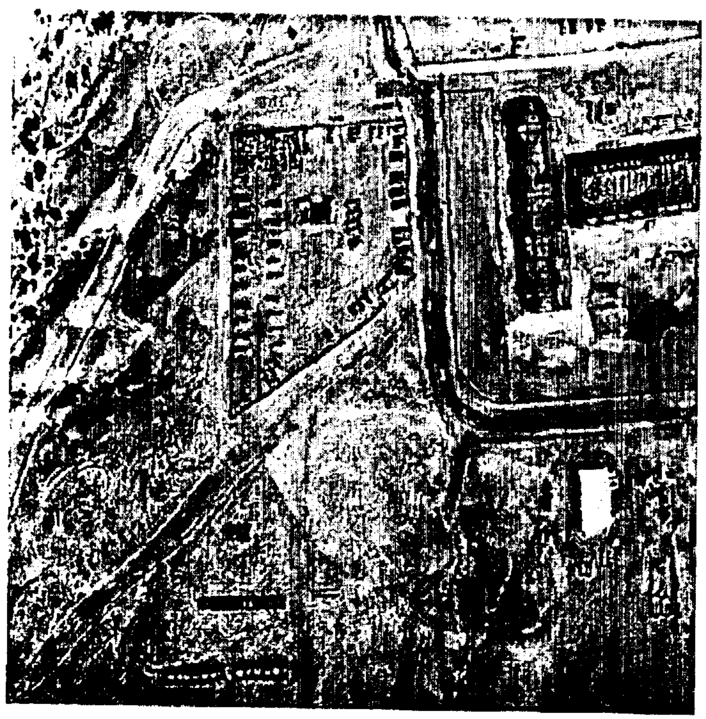
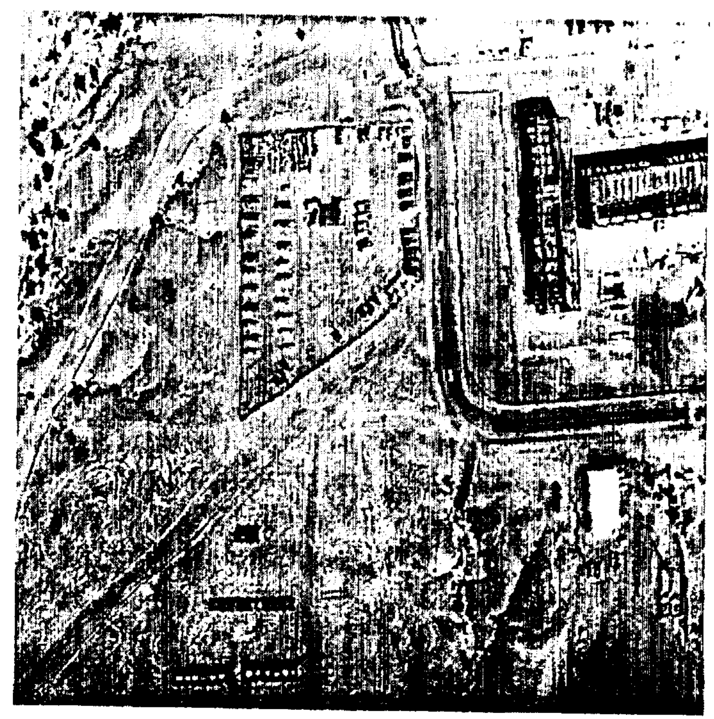
Visual Model

partial vision model



full vision model



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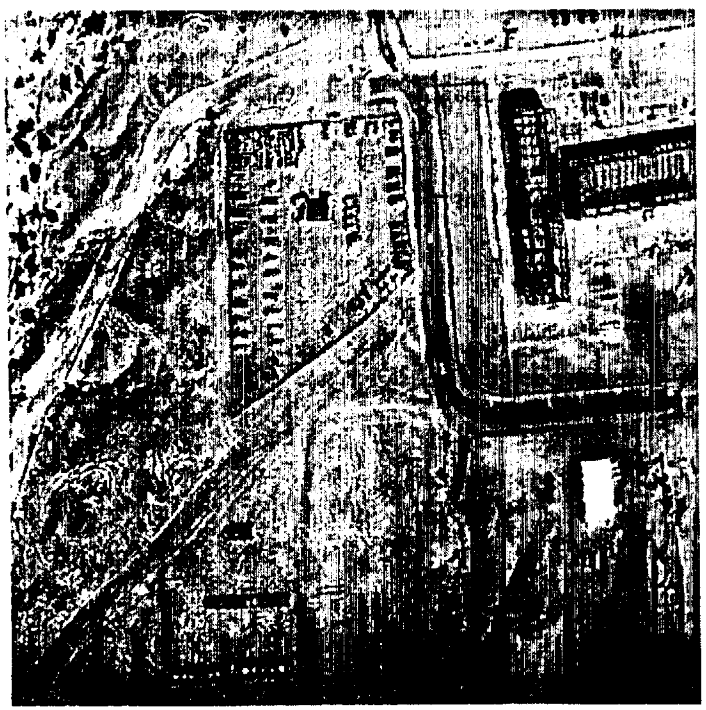
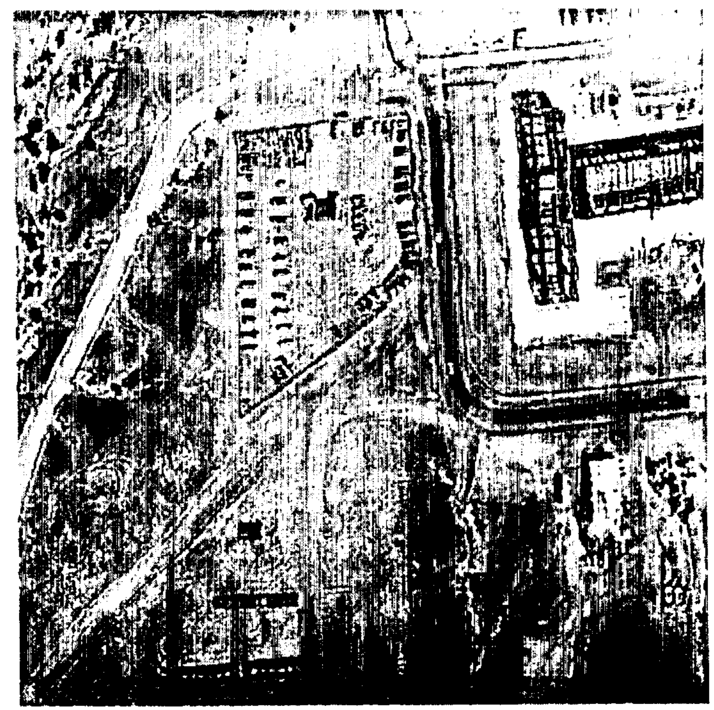
Depth Cues

no correction



corrected for depth cues



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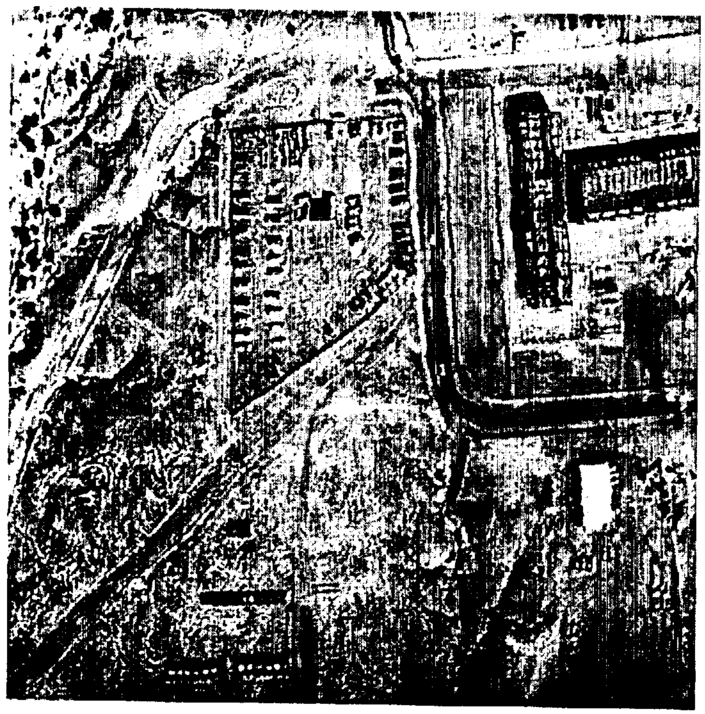
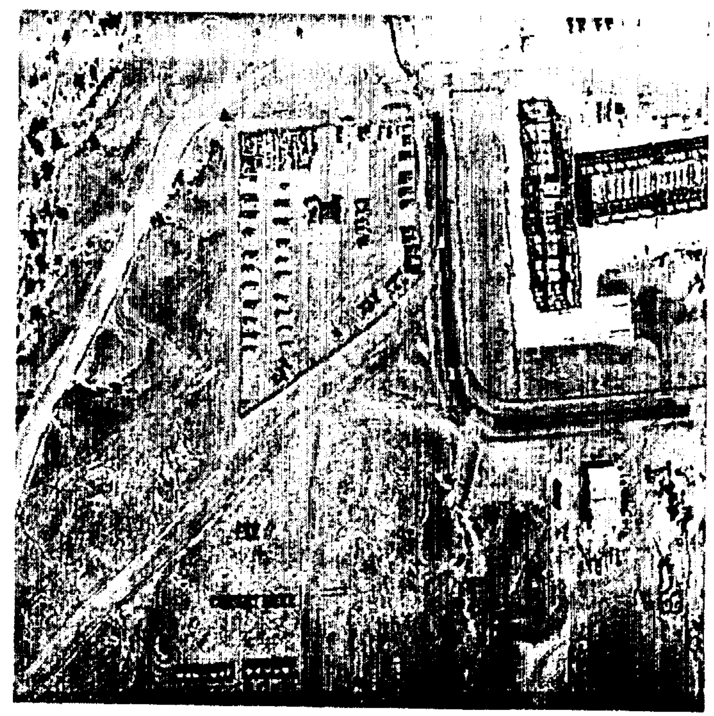
Weighted Summation

Binary selection



Weighted sum



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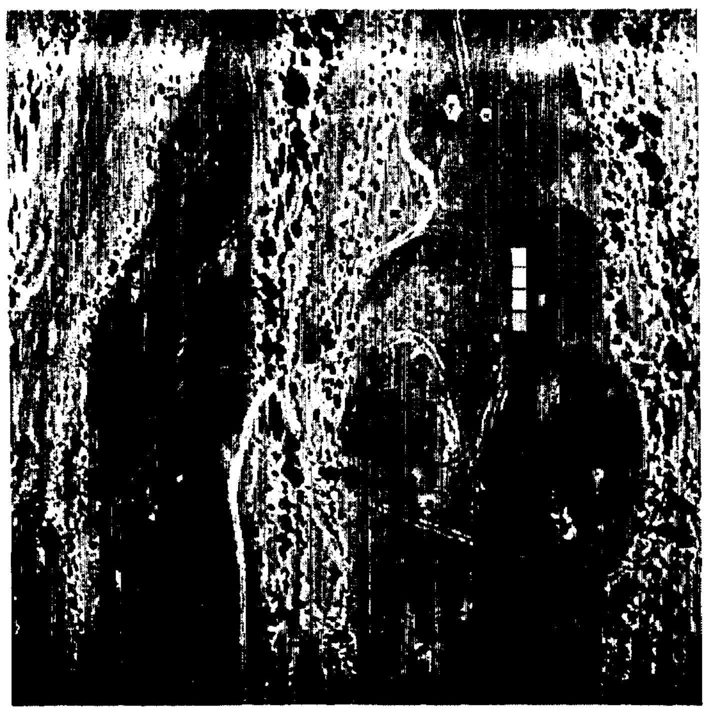
Normalized Images

Visual



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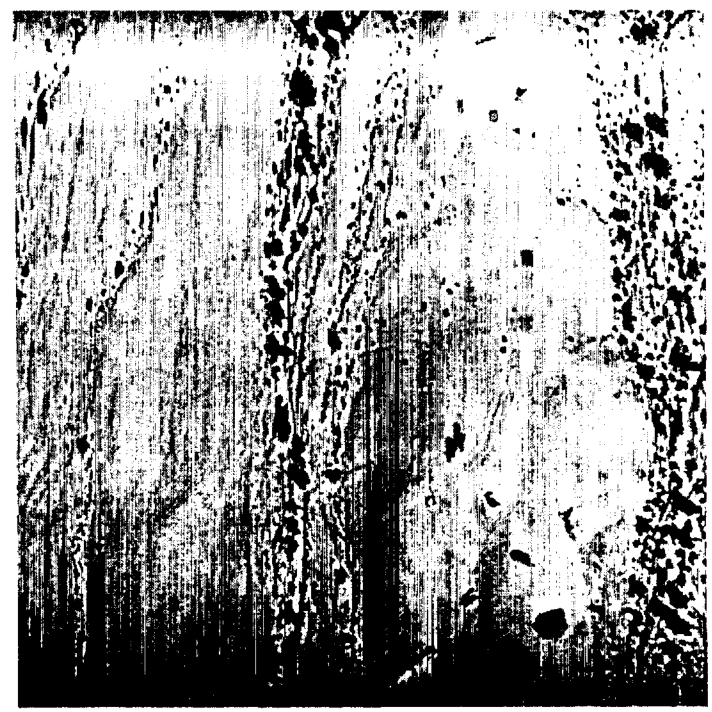

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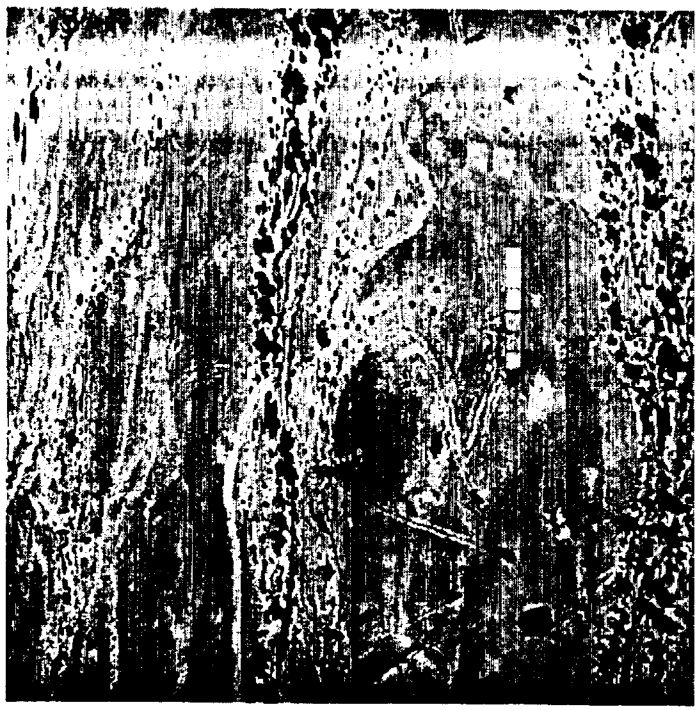
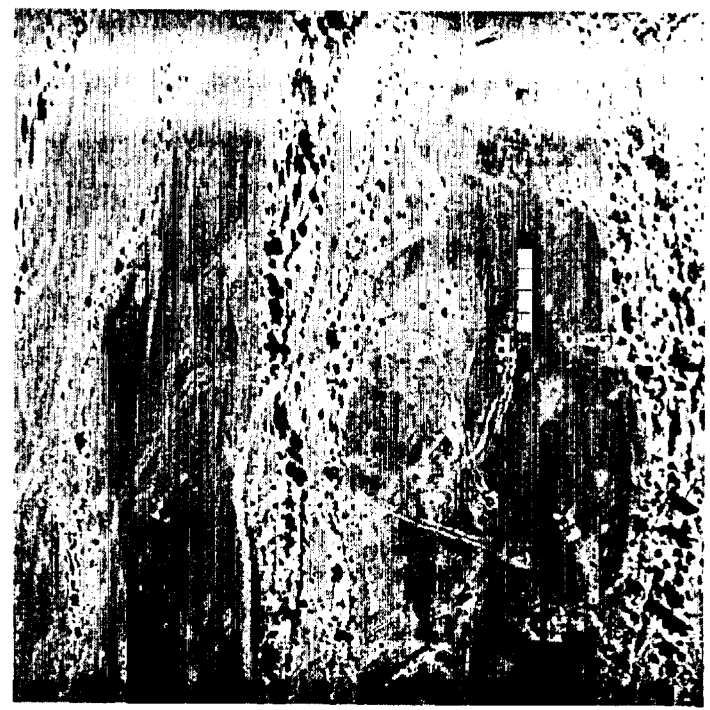
Depth Cues

no correction



corrected for depth cues



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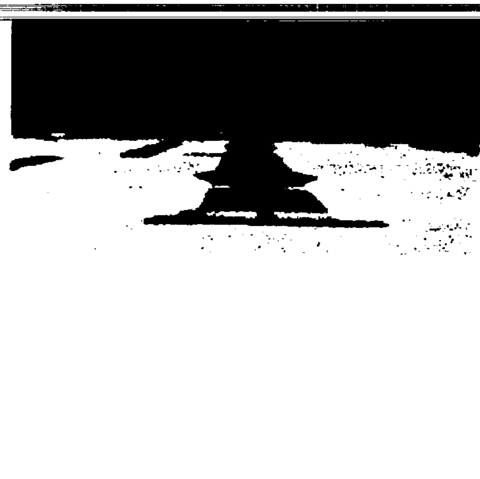
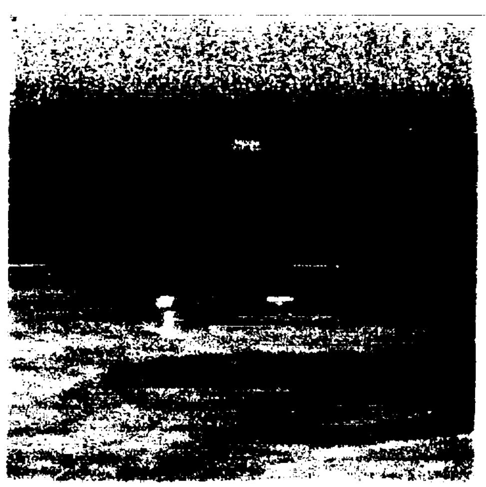


Mid Wave IR

Long Wave IR



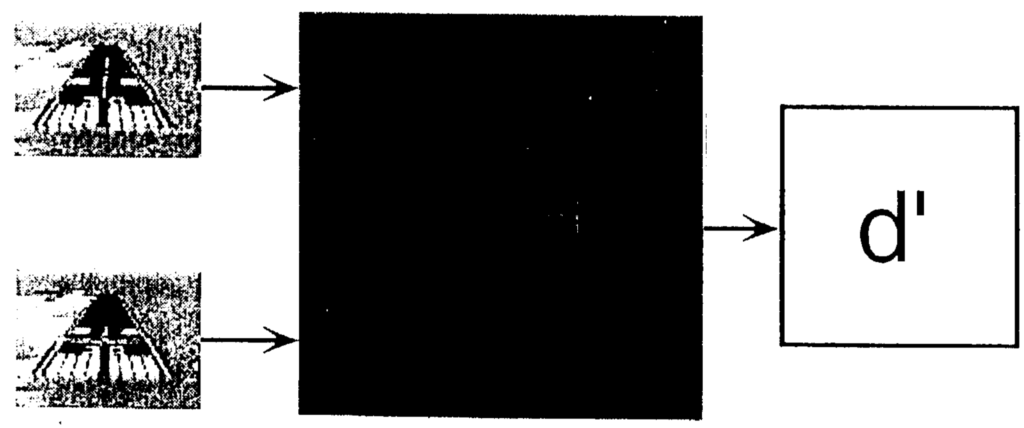
YIQ Fusion

Complementary Fusion

S26-54

Close

Image Discrimination Models



Flight Management & Human Factors Division

13

Human Observer Model

- Prediction of target detection and recognition
- Uses image discrimination models
- Current Performance--Static, gray scale, foveal images
- Future Plans--Dynamic, color, and wide field images

Flight Management & Human Factors Division

Some Thoughts On Sensors

Synthetic Vision Workshop

27 - 29 January 1998

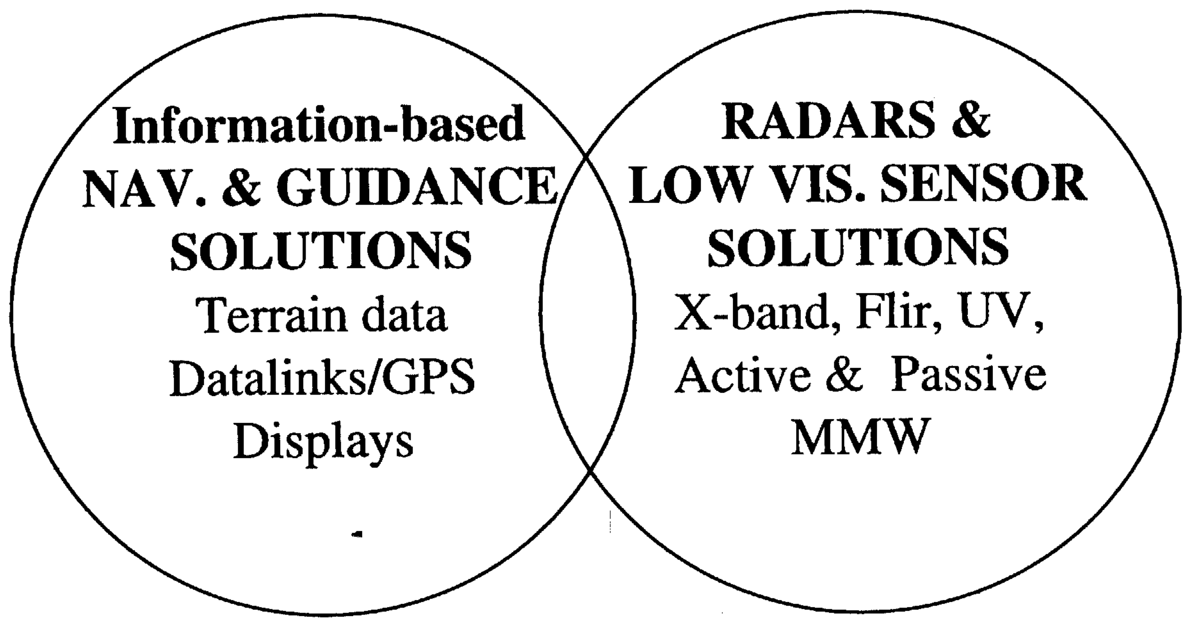
Axioms

- User community is usually sensor illiterate (or worse, partially literate)
- Whether image display comes from a real time image of the scene out the aircraft window or from information stored in a computer database, the source is always a sensor
  - Understanding sensor capabilities is crucial (either for terrain, or for imaging, or for other out of the aircraft measurements)
- NASA is the only agency that can lead in filling this void
- A sound set of requirements for solving “CFIT and visibility induced crew errors” can easily lead to plausible S/EVS architecture(s) definitions
- A successful S/EVS thrust should present the various aviation sectors with responsive architectures leveraging a broad spectrum of available sensors/technological approaches

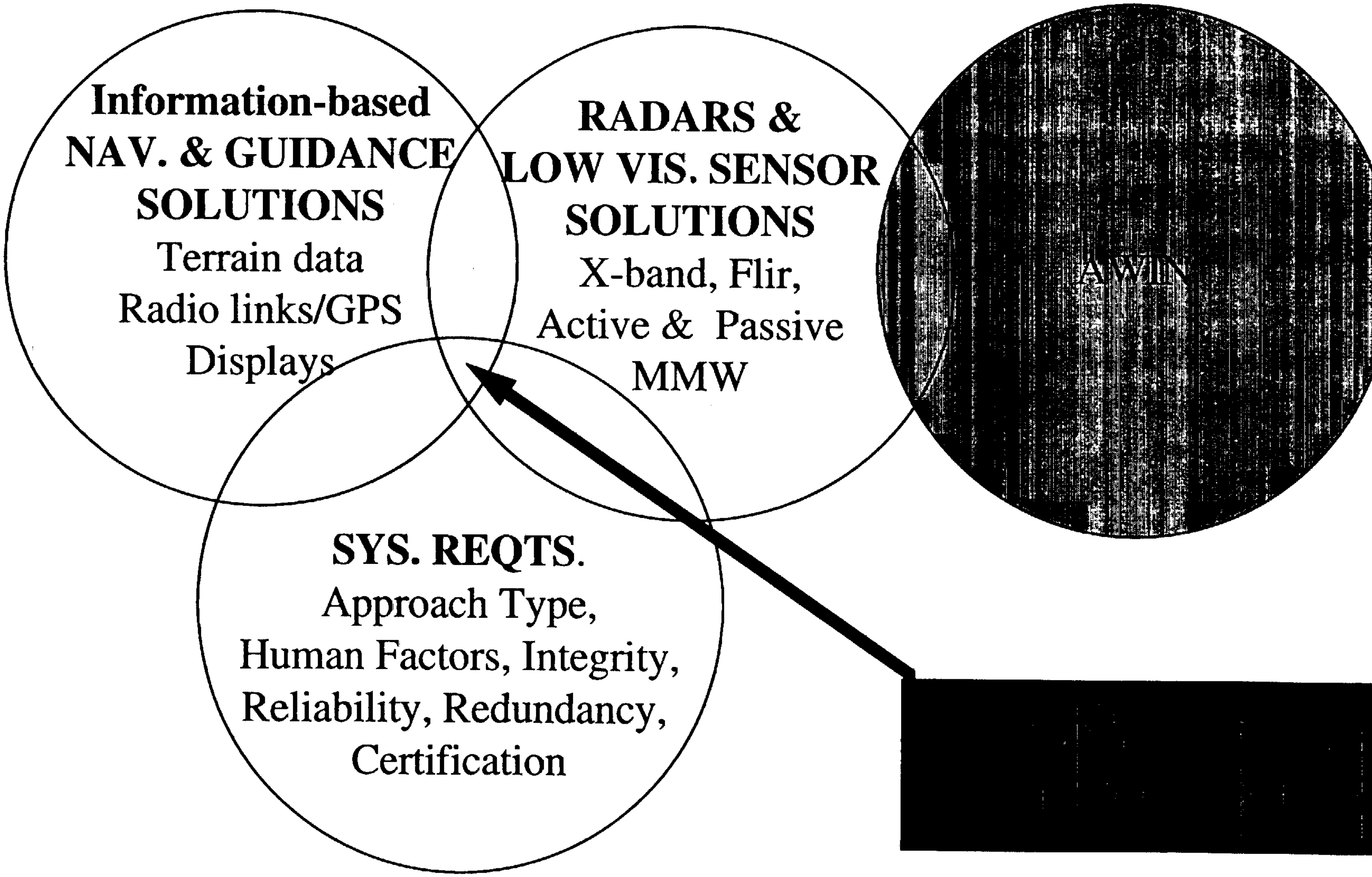
"To Solve CFIT and visibility induced errors" A Terrain Database Is the Answer - *A Monocular View*

Information Based
NAV. & GUIDANCE
SOLUTIONS
Terrain data
Datalinks/GPS
Displays

"To Solve CFIT and visibility induced errors" Terrain Data Is Augmented with Enhanced Vision Sensors - *A 2-Dimensional View*



"To Solve CFIT and visibility induced errors"
Let Us Not Put the Cart Before the Horse
A 3-Dimensional View



Feedback to the Safety Program S/EVS Thrust

- NASA should lead into the future rather than work on technologies that are finding their way to the market: to solve the problem at hand a system look is warranted, there are more than just terrain database and displays out there
- Architectures, technology trades and evaluation, concepts, and human factors should be focus areas for the SVS Thrust and NASA's upcoming NRA - let industry develop the terrain databases and the sensors
- NASA can play a unique role in making sensors better understood by users, policy makers, and administrative bodies (windshear example)

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
March 1999

3. REPORT TYPE AND DATES COVERED
Conference Publication

4. TITLE AND SUBTITLE
Synthetic Vision Workshop 2

5. FUNDING NUMBERS
522-19-11-01

6. AUTHOR(S)
Lynda J. Kramer, Compiler

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
NASA Langley Research Center
Hampton, VA 23681-2199

8. PERFORMING ORGANIZATION REPORT NUMBER
L-17838

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA/CP-1999-209112

11. SUPPLEMENTARY NOTES
Primarily Viewgraphs

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified-Unlimited
Subject Category 03 Distribution: Nonstandard
Availability: NASA CASI (301) 621-0390

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The second NASA sponsored Workshop on Synthetic/Enhanced Vision (S/EV) Display Systems was conducted January 27-29, 1998 at the NASA Langley Research Center. The purpose of this workshop was to provide a forum for interested parties to discuss topics in the Synthetic Vision (SV) element of the NASA Aviation Safety Program and to encourage those interested parties to participate in the development, prototyping, and implementation of S/EV systems that enhance aviation safety. The SV element addresses the potential safety benefits of synthetic/enhanced vision display systems for low-end general aviation aircraft, high-end general aviation aircraft (business jets), and commercial transports. Attendance at this workshop consisted of about 112 persons including representatives from industry, the FAA, and other government organizations (NOAA, NIMA, etc.). The workshop provided opportunities for interested individuals to give presentations on the state of the art in potentially applicable systems, as well as to discuss areas of research that might be considered for inclusion within the Synthetic Vision Element program to contribute to the reduction of the fatal aircraft accident rate. Panel discussions on topical areas such as databases, displays, certification issues, and sensors were conducted, with time allowed for audience participation.

14. SUBJECT TERMS
Aviation Safety; Synthetic Vision systems; Enhanced Vision systems; Controlled Flight Into Terrain accidents; Loss of Control accidents

15. NUMBER OF PAGES
391

16. PRICE CODE
A17

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL